MERC/CR-77-2

THREE LICK BED:
USEFUL STRATIGRAPHIC MARKER IN THE UPPER DEVONIAN SHALE IN EASTERN KENTUCKY

FOSSIL ENERGY

by

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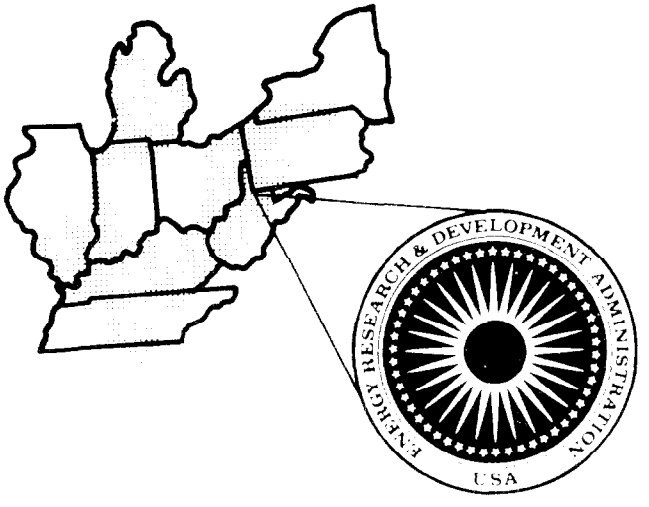
January 1977

EASTERN GAS SHALES PROJECT



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USERDA Technical Information Center, Oak Ridge, Tennessee

MERC/CR-77-2
Distribution Category UC-92a

THREE LICK BED: USEFUL STRATIGRAPHIC MARKER IN UPPER DEVONIAN SHALE IN EASTERN KENTUCKY AND ADJACENT AREAS OF OHIO, WEST VIRGINIA AND TENNESSEE

by

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This work partially supported
under the following ERDA contracts:
E(49-18)-2287, E(40-1)-5201

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ABSTRACT

The internal stratigraphy of almost any sedimentary resource - be it a coal bed, an evaporite, or an aging oil field programmed for secondary recovery - is a vital first step for evaluating its full resource potential. Because this is also true of the gas potential of the Upper Devonian black-shale sequence of the Appalachian basin, we have identified and named a useful marker bed, the Three Lick Bed, in the upper part of the Ohio Shale and its equivalents in eastern Kentucky and in nearby Ohio, West Virginia, and Tennessee.

The Three Lick Bed consists of three greenish-gray shale beds separated by fissile, brownish-black shale. These distinctive greenish-gray shale beds are easily recognized in outcrop in seven sections on the east flank of the Cincinnati arch from southern Ohio into Tennessee, have a distinctive signature on wire-line logs, and can be identified in well cuttings over much of eastern Kentucky and adjacent parts of Ohio and West Virginia. The Three Lick Bed correlates with the middle unit of the Gassaway Member of the Chattanooga Shale in Tennessee and with the lower part of the Camp Run Member of the New Albany Shale in Indiana.

Key ideas: Upper Devonian black-shale sequence, Appalachian basin, widespread marker bed, stratigraphy, sedimentology, and natural gas potential.

INTRODUCTION

The Upper Devonian black-shale sequence is present in most of the Appalachian basin (Figure 1) and has long produced natural gas in eastern Kentucky and parts of West Virginia and southern Ohio.

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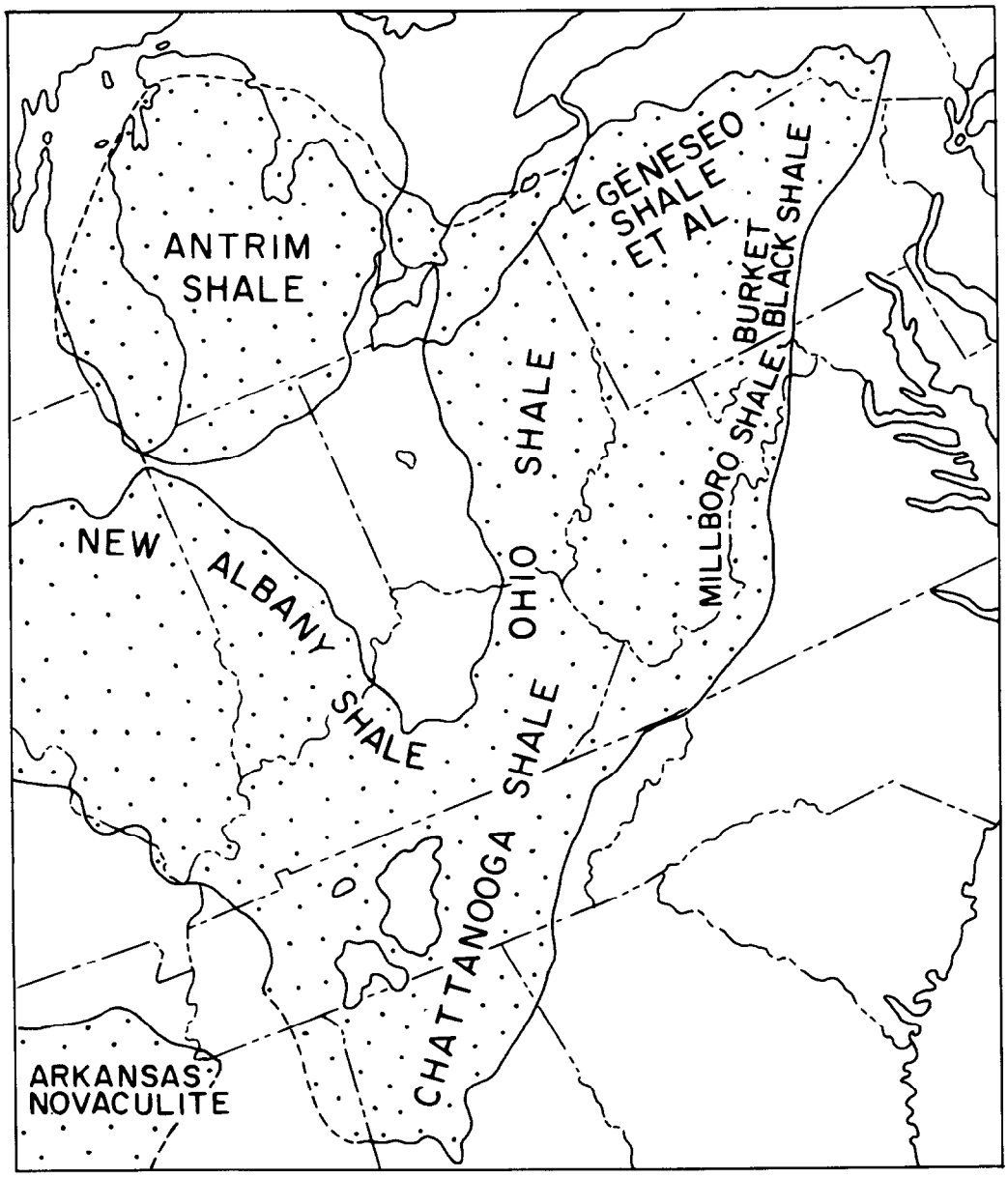

FIGURE 1.- Study area, regional distribution of Upper Devonian black-shale sequence and principal stratigraphic names in eastern United States. Area underlain by shale sequence is stippled. (Redrawn from Conant and Swanson, 1961, pl. 14.)

Three key questions about this gas production are: What controls its present distribution? How can we enhance production from existing wells? And how can we find natural gas from the shale sequence outside present producing areas? In addition to such factors as the fracture and thermal history of the black-shale sequence and the type and abundance of original organic matter, we believe the internal stratigraphy of the shale sequence will prove fundamental for better utilization of its contained natural gas. The Upper Devonian shale sequence contains

diverse lithologies that have different sedimentological, chemical, and engineering characteristics and, consequently, respond differently to post-depositional events. Thus, gas production and stimulation techniques will most probably vary both vertically within the shale and geographically within the basin as well. An additional factor is simply its thickness - in eastern Kentucky as much as 1,700 feet is present; in southern Ohio 1,000 feet; and in west-central West Virginia 2,500 feet.

Recognition of key beds within the shale sequence is the first step toward establishing a useful internal stratigraphy (Figure 2). The Three Lick Bed named in this report is such a key bed. The Three Lick Bed occurs in the upper third of the shale sequence over a wide area in eastern Kentucky and adjacent parts of adjoining states, is always thin relative to the total thickness of the Upper Devonian shale sequence, and is easily recognizable in both outcrop and the subsurface, especially on gamma-ray logs.

Others who have recognized subdivisions within the shale sequence in the Appalachian basin and nearby in the Illinois basin include Lineback (1968 and 1970) in Indiana, Conant and Swanson (1961) in Tennessee, Hoover (1960) and Lewis and Schwietering (1971) in parts of Ohio, and Campbell (1946) in Kentucky. A general summary of stratigraphic nomenclature for the Appalachian basin, one that nicely shows the stratigraphic complexity of the Upper Devonian black-shale sequence as it is traced eastward from the outcrop along the west side of the basin into western New York and Pennsylvania and into eastern West Virginia, is that of Oliver and others (1969).

Our study includes both the outcrop and subsurface. The outcrop sections are all easily accessible and most are not far from wells with wire-line logs, so that the subsurface is easily related to the outcrop.

To facilitate study of the black-shale sequence by explorationists, geochemists and paleontologists, we have included our detailed descriptions of ten outcrop sections in the Appendix. They include two in southern Ohio, two in Tennessee, and the remainder in Kentucky (Figure 3). Of these, most are from exposures on the west side of the Appalachian basin where the shale is relatively thin. Two incomplete sections (Figure 3, secs. 9 and 10) were also measured in tilted strata in the folded belt, where the Upper Devonian sequence is much thicker. Radioactivity profiles were made of each measured section as an aid in correlating the surface units with wells for which gamma-ray logs are available. Colors are based on the Rock-Color Chart (Goddard, 1963).

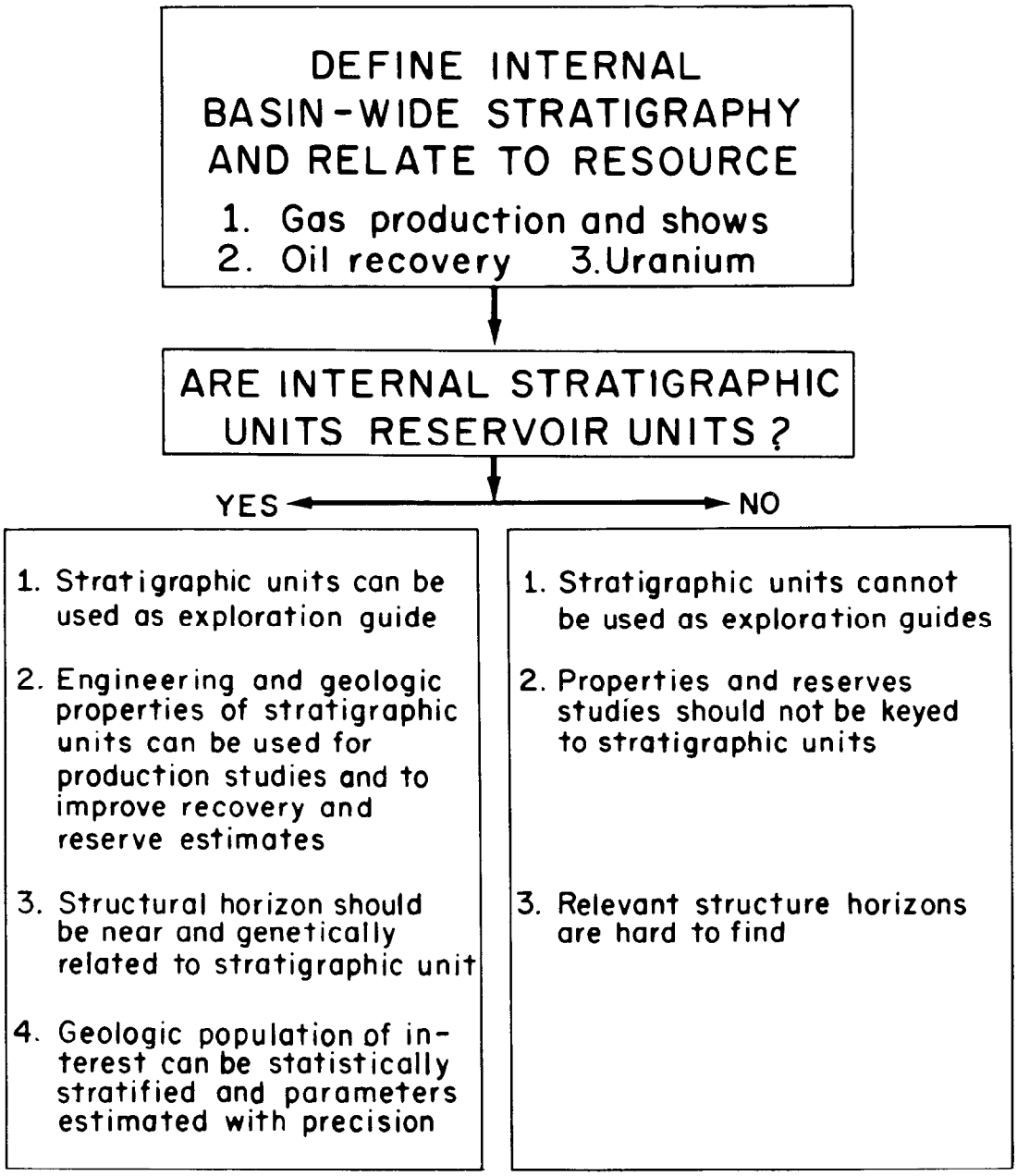

FIGURE 2.- Role of internal stratigraphy and resource appraisal of Upper Devonian shale sequence.

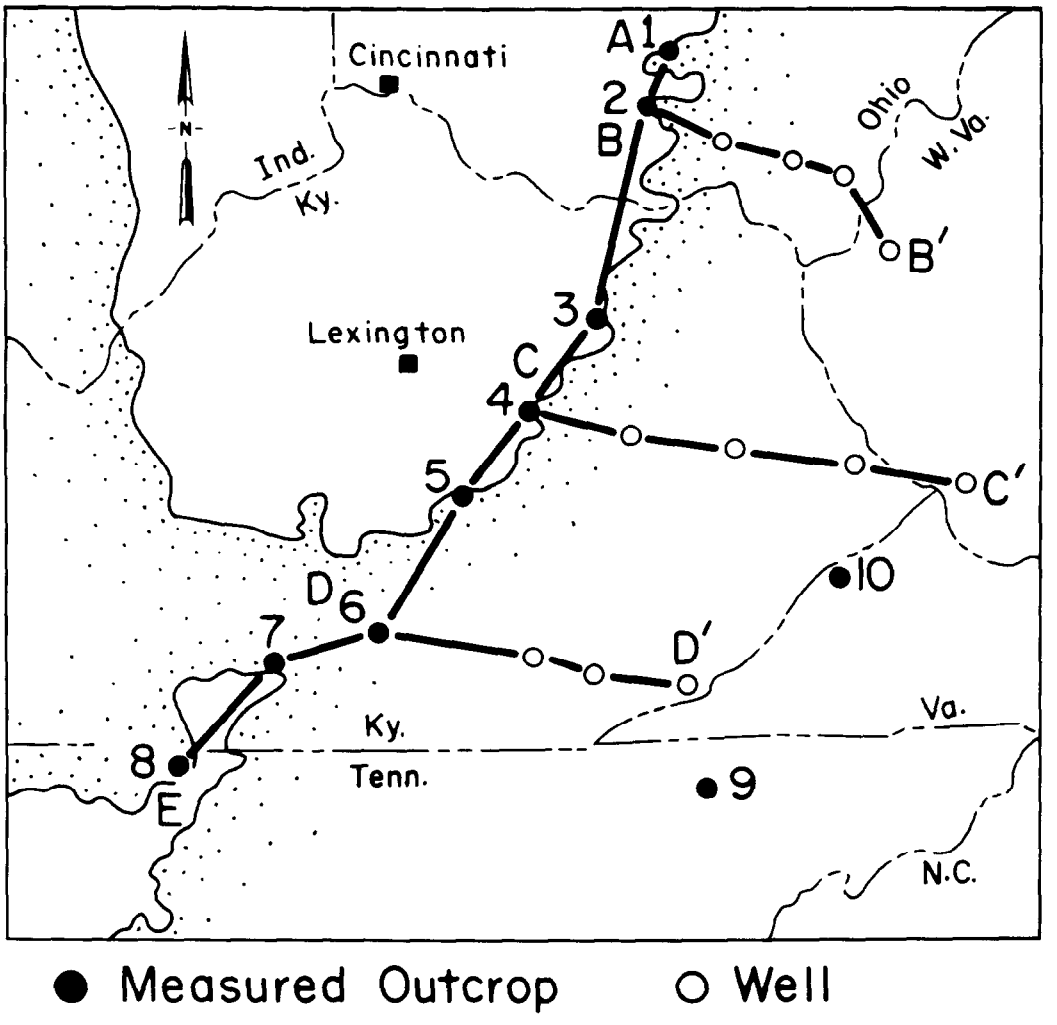

FIGURE 3. -Location of outcrop and subsurface sections of this report. Area underlain by shale on stippled side of outcrop; southeastern extent not shown. See Table 1 and Appendix for detailed locations.

LITHOLOGY

The Upper Devonian shale in outcrop section is predominantly brownish-black to olive-black carbonaceous shale. Less common, but locally conspicuous, are thin beds of greenish-gray shale, siltstone, and dolomite, and a very small amount of limestone, mostly with cone-in-cone structure. (See Figure 4 and measured sections in the Appendix for details.)

The black shale, where fresh, is massive, dense, and fractures subconchoidally. Upon weathering, it progressively breaks into fissile, brittle, bleached plates and chips. Pyrite is abundant as scattered spherules, blebs, aggregates, and nodules, which are locally concentrated

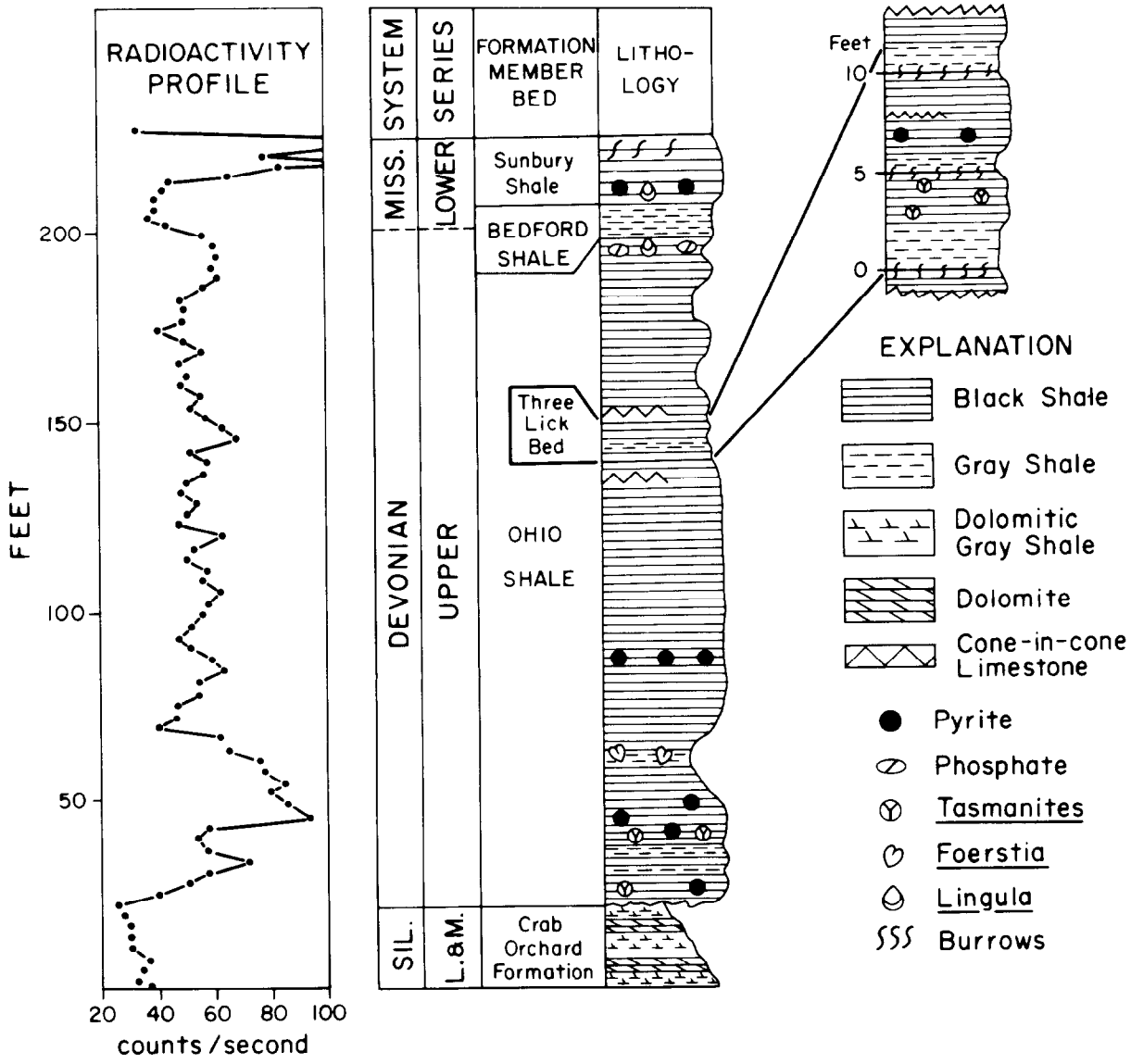

FIGURE 4. -Columnar section with radioactivity profile of Ohio Shale at type locality of Three Lick Bed near Morehead, Rowan County, Kentucky. (See Appendix, Sec. 3.)

along bedding planes. Phosphate nodules, as ovoid to amoebiform masses, are common in the upper part of the black shale and in most of the area form a persistent horizon in the upper foot as well as in the overlying greenish-gray shale of Mississippian age. Joints and bedding plane surfaces are commonly coated by white and yellowish sulfate and reddish and brownish oxide resulting from the weathering of pyrite.

Dolomite is locally present in the lower part of the shale (Sections 2, 3, 4, 5, and 6: Figure 3). Siltstone is common in easternmost

outcrops (Sections 9 and 10; Figure 3). Medium-grained, well-rounded quartz sand is common at the base of the shale as a single bed or as scattered grains (Summerson and Swann, 1970, p. 476) and occurs in six of the measured sections (Sections 3, 4, 5, 6, 7, and 8).

Common fossils are conodonts and the round spore-like Tasmanites (Wall, 1962); coalified wood fragments of Callixylon and phosphatic remains of linguloid and orbiculoid brachiopods and fish parts are locally common on bedding planes. The fossil alga Foerstia is found in sections 2 through 5 and 10 (Figure 3) in a zone which ranges in thickness from 3 to 43 feet. (See Schopf and Schwietering, 1970.)

Greenish-gray shale and shaly mudstone is pyritic, silty, and locally concretionary. Illite is the chief clay mineral and muscovite is common. Upon weathering, the shale slakes to yellowish gray clay, less resistant than the weathered black shale, and commonly produces recessive layers which are readily covered by talus from overlying units. Fossils include sparse conodonts, Tasmanites, linguloid brachiopods, and burrows.

Greenish-gray shale occurs in three widespread zones in the Devonian black-shale sequence. One of these zones is near the base of the shale at sections 3 and 4 (Figure 3) in Kentucky. Another zone is prominent near the middle of the shale as described from section 2 in Ohio. In both of these lower zones, the gray shale is interbedded with black shale in many thin couplets.

The third zone occurs in the upper part of the sequence and is distinguished by three beds of persistent greenish-gray shale separated by black shale. (See Figure 4.) This zone has been traced in the outcrop from Ohio to Tennessee (Figure 3) and can be recognized in the subsurface eastward from the outcrop (Figure 3). The Three Lick Bed is here proposed as a name for this useful and distinct stratigraphic marker.

THREE LICK BED

Location and Thickness

The Three Lick Bed is named for a small creek, Three Lick Branch, 1.8 miles north of the type section. The type section is along Interstate Highway 64 in western Rowan County, Kentucky (Figure 5). Here, the bed is part of the Ohio Shale as mapped on the Farmers quadrangle by McDowell (1975). Throughout most of the outcrop area the bed ranges in thickness from 1.7 feet at Creelsboro, Russell County, Kentucky (Section 7, Figure 3), to 20 feet at Copperas Mountain, Ross County, Ohio (Section 1, Figure 3). Thicknesses of the individual greenish-gray subunits range from less than a centimeter at Creelsboro, Kentucky, to 5 feet at Copperas Mountain, Ohio. In the outcrop near Celina, Tennessee (Section 8,

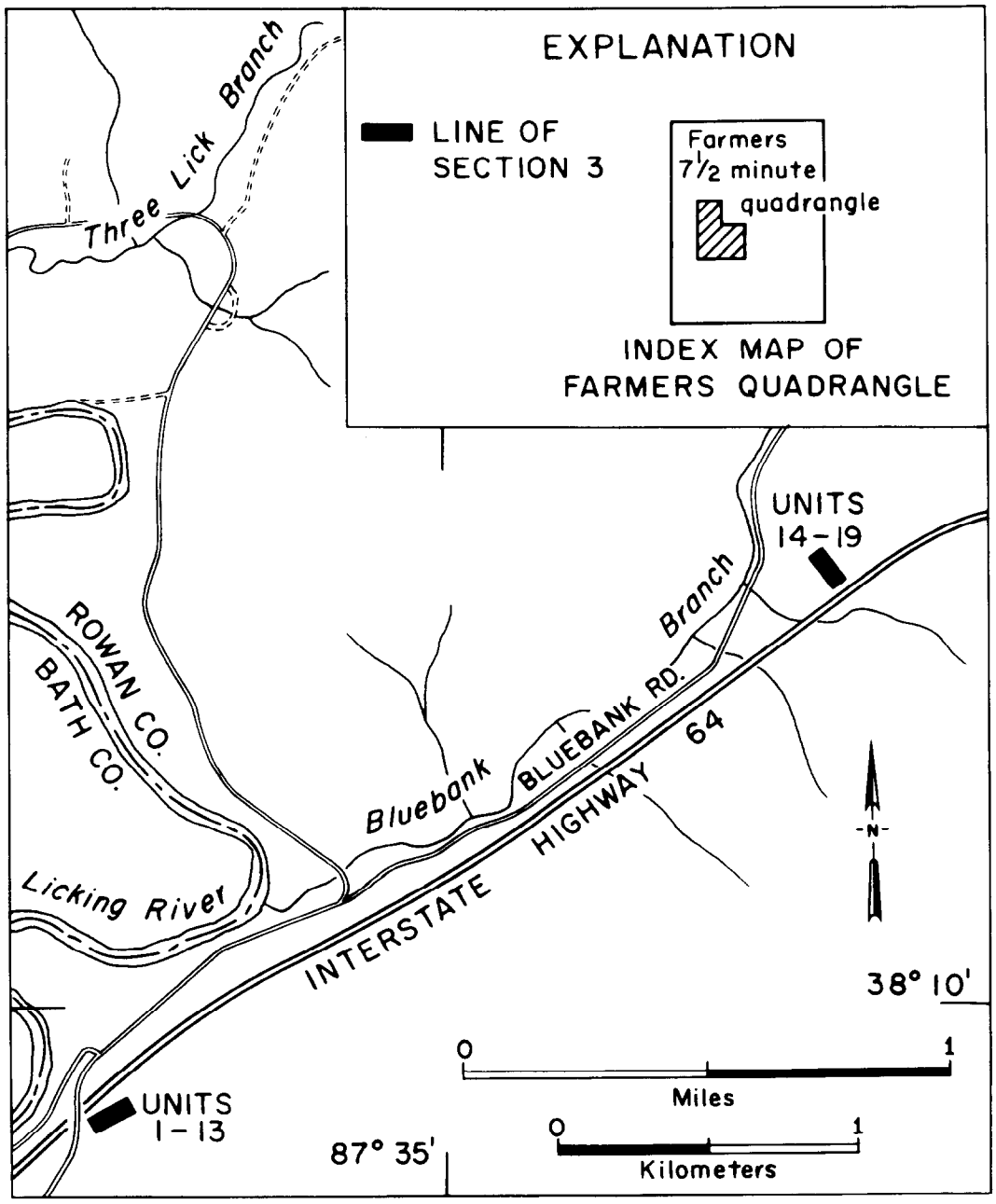

FIGURE 5. -Location map of type section of Three Lick Bed. Detailed description and location given in Appendix, Section 3.

Figure 3) the Three Lick Bed is not present, but burrowed black shale in three zones less than 0.1 foot thick probably brackets the correlative interval.

Characteristics

In outcrop the Three Lick Bed is conspicuous by its greenish-gray color, plasticity, lack of silt, presence of thin discontinuous carbonate layers with cone-in-cone structure, and burrowed zones which lie at the bases of the greenish-gray shale beds. Burrows are both horizontal and vertical and typically are gently curved, with smooth sides; some are filled with pyrite. Thickness of the burrowed zone is 3-5 centimeters. Rare burrows in the greenish-gray shale decrease in abundance upward in each bed.

In the subsurface, recognition of the Three Lick Bed depends on interpretation of subsurface data, particularly gamma-ray logs and well cuttings. The response of the gamma-ray curve to the Three Lick Bed is both distinctive and easily recognized. Variations in the natural radioactivity between these three greenish-gray shale beds and the intervening black shale result in three closely spaced negative deviations on the gamma-ray curve (Figure 6),which are readily separable from the zones of more highly radioactive black shale above and below the Three Lick Bed. This characteristic gamma-ray signature was first identified by correlation of the standard outcrop section (Section 3) of the Three Lick Bed with a gamma-ray log of a nearby well. There is a similar response in formation-density curves, which show the marked contrast between greenish-gray shale of greater grain density and less dense, organic-rich black shale. Further substantiation of this correlation is provided by well samples in which two shale types, greenish-gray and black, are present at the level of the Three Lick Bed. Thus, by subsurface correlation, the Three Lick Bed may be traced over much of Kentucky and into the bordering states of Ohio, West Virginia, and Tennessee (Figures 3, 7, and 8).

The Three Lick Bed attains a maximum subsurface thickness of approximately 75 feet in Boyd County, northeastern Kentucky. In wells located near the outcrop belt, this bed thins to as little as 15 feet. In relatively thin subsurface sections such as those in south-central Kentucky and northern Tennessee, however, identification of the Three Lick Bed in wire-line logs is not possible with any degree of certainty.

Deeper in the Appalachian basin, the Three Lick Bed thickens to a maximum in Boyd County, Kentucky, very near the Kentucky-West Virginia state line. Further east, however, the bed appears to thin to about 35 feet in western West Virginia. Eastward thinning of the Three Lick Bed may be only apparent. The distinctive gamma-ray signature of the Three Lick Bed becomes increasingly less recognizable east of longitude 82° west (Figure 8) because the units above and below the Three Lick Bed are significantly less radioactive in this part of the basin. This decrease in radioactivity is probably due in part to more gray shale and siltstone than black shale in the section, and in part to dilution of radioactivity in the black shale. The Three Lick Bed is also indistinguishable in the easternmost outcrops (Sections 9 and 10) where gray shale and siltstone rather than black shale predominate.

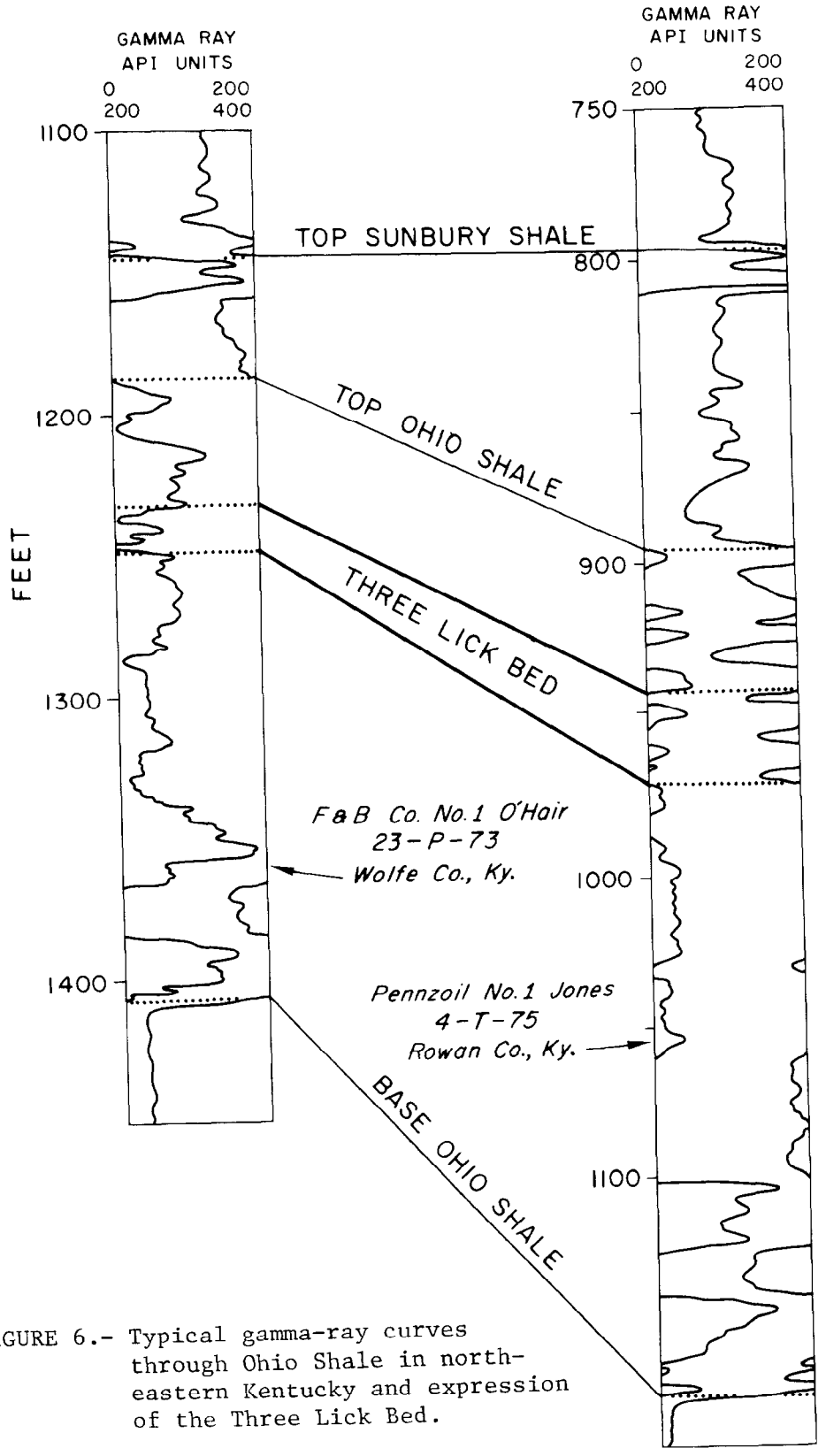

FIGURE 6.- Typical gamma-ray curves through Ohio Shale in northeastern Kentucky and expression of the Three Lick Bed.

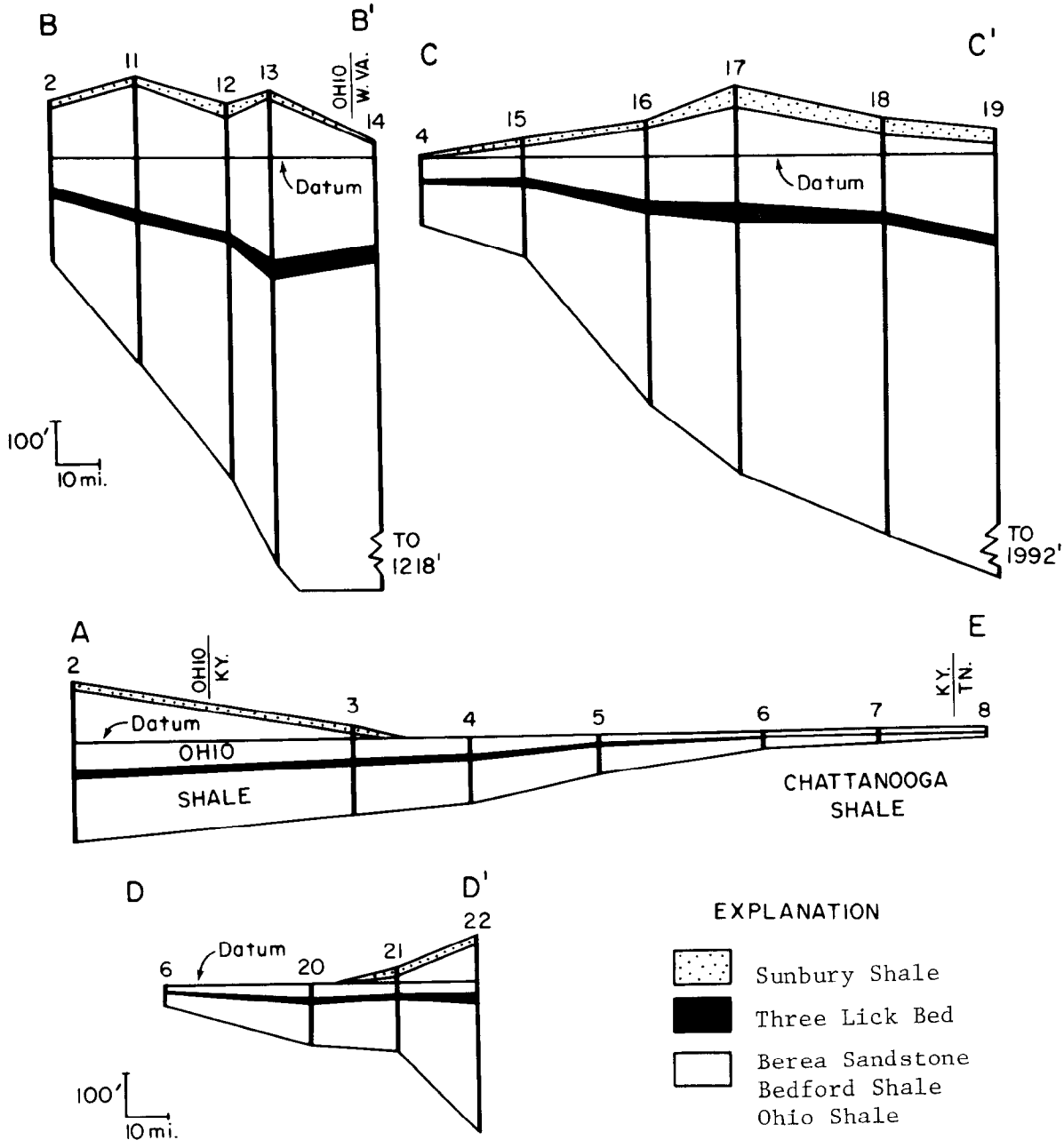

FIGURE 7. -Schematic cross sections of the Three Lick Bed in the Ohio Shale in eastern Kentucky and nearby. Datum is top of Ohio shale; undivided Bedford Shale and Berea Sandstone overlie datum. (See Figure 3 for lines of section; numbers refer to well locations in Table 1.)

TABLE 1

OUTCROP SECTIONS AND WELLS USED IN CONSTRUCTION OF CROSS SECTIONS

Part A: Outcrops (see also Appendix)

1. Copperas Mountain, Ross Co., OH
2. Tener Mountain, Adams Co., OH
3. Interstate 64, Rowan Co., KY
4. Mountain Parkway, Powell Co., KY
5. Berea, Madison Co., KY
6. Big Clifty Creek, Pulaski Co., KY
7. Creelsboro, Russell Co., KY
8. Pleasant Grove, Clay Co., TN
9. Flat Gap Road, Hawkins Co., TN
10. Mountain Branch, Pike Co., KY

Part B: Wells with wire-line logs

11. Continental Oil No. 1 Shisler
Permit #194
Valley Township, Sec. 55
Scioto County, OH

12. R. Weed No. 1 Cambria Clay
Permit #170
Washington Township, Sec. 11
Lawrence County, OH

13. Quaker State Oil and Refining No. 1-1101 Gills and Green
Permit #151
Perry Township, Sec. 28
Gallia County, OH

14. Westrans Petroleum No. 1 Perry
Permit #532
16-X-87
Cabell County, W VA

15. F & B No. 1 O'Hair
23-P-73
Wolfe County, KY

16. San Juan Oil No. 1 Allen
13-0-79
Magoffin County, KY

17. United Fuel Gas No. 9475 McGuire
18-0-82
Floyd County, KY

18. Kentucky West Virginia Gas No. 6418 Morris
19-N-86
Pike County, KY

19. United Fuel Gas No. 9428 United Fuel Gas Mineral Tr. 10
13-R-88
Permit #781
Mingo County, W VA

20. Petroleum Exploration No. 1 Westerfield
12-F-67
Knox County, KY

21. Joe Cook No. 2 Baker
16-E-70
Knox County, KY

22. Columbian Carbon No. 1 Kentenia
16-D-74
Harlan County, KY

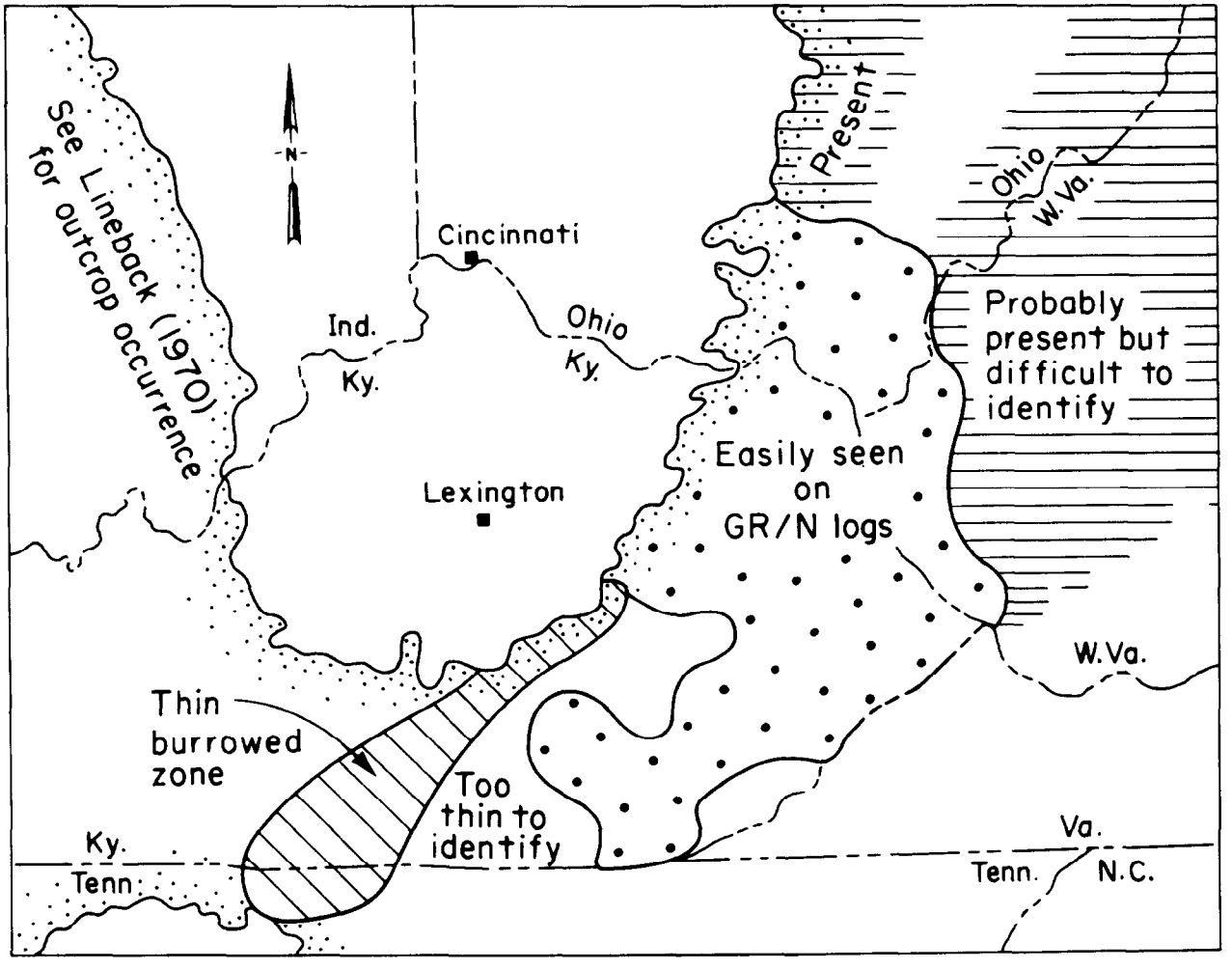

FIGURE 8. -Extent of Three Lick Bed recognized in this study.

Correlation

Correlation of the Three Lick Bed with adjacent areas is complicated by a lack of uniformity in names applied to the Devonian-shale sequence, even within Kentucky (Figure 1). The best correlation is with the middle unit of the Gassaway Member of the Chattanooga Shale as described by Conant and Swanson (1961, p. 39-40, loc. 78). They noted the widespread nature of the unit and recognized it in exposures as far north as Wolf Creek Reservoir (Lake Cumberland, near section 6 of this report, Figure 3), which also corresponds to their locality 6.

In north-central Kentucky and southern Indiana, the Three Lick Bed correlates with the lower part of the Camp Run Member of the New Albany Shale (Lineback, 1970). Lineback describes the lower Camp Run Member

(p. 25), "Three greenish-gray shale beds, each about one foot thick and separated by brownish-black shale beds of about the same thickness, lie at the base of the member."

In southern Ohio, correlation is less clear. Most of the subdivisions of the Ohio Shale are named from type localities in the northern part of the state (Hoover, 1960, p. 5-6). We hesitate, therefore, to venture a correlation. Measured sections 1 and 2 (Figure 3) and cross sections (Figure 7) provide a basis for future study of possible correlatives of the Three Lick Bed in the surface and subsurface of Ohio.

Origin and Lateral Continuity

What can be said at present about the origin of the Three Lick Bed, primarily based only on field observations?

The three greenish-gray shale beds of the Three Lick Bed differ from the interbedded brownish-black shale in having somewhat less silt and containing far less organic matter. They also contain a few linguloid brachiopods and some scattered burrows. Additionally, at the base of each of the three greenish-gray beds, there is a markedly burrowed zone, which suggests a pause or slowing of sedimentation, or an increase in oxygenation prior to or during the deposition of the overlying greenish-gray mud. The burrowing at the base of each of the greenish-gray shale beds demonstrates that they cannot be bentonites as such a sudden event as an ash fall would have an adverse effect on benthic fauna. Comparison of the clay mineralogy of the greenish-gray shale beds in the Three Lick Bed with that of their associated beds would provide a test of this idea.

Evidently there was a pause in sedimentation over a very wide area in much of present-day Kentucky and parts of Indiana, Ohio, and Tennessee, and this pause was accompanied by a cessation of production or preservation of organic material. What caused this, we do not know at present. Perhaps a change in paleocirculation within the basin, one that created mildly oxidizing rather than reducing conditions? Or is this change related to provenance? Tracing, if possible, the Three Lick Bed northeastward and eastward into its lateral equivalents would be most helpful in determining its origin.

The lateral continuity of thin units in shale sequences is commonly very great, the example of the Three Lick Bed being no exception. Where we know it, the Three Lick Bed covers an area of 14,290 square miles (37,011 square km.) and future work will probably extend this area, certainly northeastward into Ohio. This area compares well with the lateral persistence of a thin (maximum thickness is 7 cm.) cone-in-cone limestone layer occurring in a Devonian black shale in the Northwest Territories (MacKenzie, 1972). This cone-in-cone layer covers an area of about 24,000 km.^{2} In the Upper Devonian shale sequence of the

Appalachian basin and nearby, shale beds, as well as zones of phosphatic nodules, cone-in-cone limestone and/or pyrite - some of which can be undoubtedly recognized on wire-line logs - are all potentially useful as thin local and possibly regional marker beds. Many of these may represent a kind of stratigraphic condensation, or hiatus within the shale sequence.

SUMMARY

The Three Lick Bed of the Ohio Shale is a useful stratigraphic marker in the Devonian black-shale sequence of eastern Kentucky and adjacent states and is easily recognized in outcrop and in the subsurface. This bed, whose thickness ranges from less than 1 foot to 75 feet, may be traced from southern Ohio into northern Tennessee. The Three Lick Bed correlates with the middle unit of the Gassaway Member of the Chattanooga Shale and with the lower part of the Camp Run Member of the New Albany Shale. Recognition of the interbedded greenish-gray and black shale of the Three Lick Bed is impossible only in very thin subsurface sections or in those sections which primarily consist of siltstone and organic-poor shale. Naming of this widespread and distinctive bed is an important initial step for subdividing the Ohio Shale into thinner units so as to relate the shale's known and future gas potential to its internal stratigraphy.

ACKNOWLEDGMENTS

The authors thank Dr. J. Barry Maynard, Messrs. Michael Lewan, Rene Ulmschneider, and Ho-Shing Yu of the University of Cincinnati for assistance in measuring, describing and profiling the sections. The cooperation and advice of Mr. E. N. Wilson, Kentucky Geological Survey; Dr. Arie Janssens, Ohio Geological Survey; Dr. Douglas G. Patchen, West Virginia Geological Survey; and Mr. Anthony T. Statler, Tennessee Geological Survey on various subsurface problems is greatly appreciated. Support for this study was provided largely by the Nuclear Fuels Branch of the U. S. Energy Research and Development Administration, Grand Junction, Colorado, under contract AT(05-1)-1650.

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APPENDIX--DESCRIPTIONS OF THE TEN MEASURED SECTIONS OF THE OHIO AND CHATTANOOGA SHALES OF THIS REPORT

SECTION 1

Copperas Mountain Section

Nearly complete section of Ohio Shale in a spectacular exposure, where Paint Creek impinges at base of and undercuts Copperas Mountain in Ross County, Ohio, approximately 3.9 airline miles east of Bainbridge by way of U.S. Highway 50, Jones Levee Road and Storm Station Road, on the Morgantown 7.5' Quadrangle (1,802,300 feet east, 450,000 feet north, Ohio coordinate system, south zone). Because of the steep slopes and cliffs, we could only obtain detailed lithologic observations at considerable hazard; and, consequently, the section was described in reconnaissance only except for some details of the Three Lick Bed. However, the section is notable for the outstanding exposure of the Three Lick Bed, which can be seen from afar when driving east on U.S. Highway 50 from Bainbridge, and for its unique system of buttresses. Described with Jacob's staff, Abney level, and tape by Roy C. Kepferle, J. Barry Maynard, Paul Edwin Potter, Wayne A. Pryor, and Rene Ulmschneider on August 31 and September 8, 1976. Scintillometer survery was made on August 31.

	Thickness (feet)
Mississippian:	
Berea Sandstone (incomplete):	
6. Sandstone, weathers yellowish gray and iron-stained and fine in dense, hard resistant beds 0.2 to 0.4 foot thick; sole marks include grooves and trace fossils. Slightly slumped; caps ridge.	2.0+
Bedford Shale:	
5. Shale, mainly covered except for lower part, which is partially exposed in a slump scar near the top of the cliff about 100 feet north of the trail. Sandstone in float in slump scar is thin-bedded and rippled and has numerous sole marks as is typical of the Bedford; mudstone is greenish gray with iron-stained siltstone concretions near base. Sharp basal contact is well exposed at base of scar but is partially covered at the highest point of the cliff 285 feet above low-water Paint Creek.	83.0
Total Mississippian (incomplete)	85+

Devonian:	Thickness (feet)
Ohio Shale (incomplete):	
4. Shale, brownish-black and blocky, forming a near vertical, jagged cliff easily seen from river level. Sharp basal contact.	65
Three Lick Bed:	
3. Mudstone and shale. Mudstone is greenish gray, weathers soft and contains minor pyrite. Shale is brownish black and forms thin fissle ledges. The mudstone forms three prominent beds; the upper is 5.0 feet, the middle is 1.7 feet, and the basal bed is 4.8 feet thick; the upper intervening black shale is 4.2 feet thick and split by a thin cone-in-cone limestone bed near its middle; the lower intervening black shale is 4.8 feet thick and contains several thin greenish-gray mudstone beds	20.5
Total Three Lick Bed	20.5
2. Shale, brownish-black, weathers to very steep flumes, many of which have thin, near vertical spectacular buttress-like divides. (We have not seen erosional patterns like this although they are reportedly common in parts of New York in the Upper Devonian shale sequence.) These buttresses extend nearly vertically from the base of the exposure to about 140 feet above Paint Creek, and then rise at about an angle of 30° up to the Three Lick Bed. Above this break in slope there is a distinct, regular banding characterized by couplets of resistant and nonresistant shale; the latter is recessive and accumulates a fine talus of light-gray weathered shale chips. Two thin, easily seen cone-in-cone limestone beds occur at 11 and 41 feet below the base of the Three Lick Bed; 35 feet below the Three Lick Bed is another less continuous thin cone-in-cone bed of limestone. About 65 feet above Paint Creek are three small concretions, 1 to 3 feet in size. Near the road, 15 to 25 feet above Paint Creek, is a zone of very large dolomitic concretions, some of which are hollow and all of which exhibit marked differential compaction in the shale; these concretions range in size from 1 to 6 feet. A thin, greenish-gray mudstone occurs beneath this zone. Some Foerstia were observed in the float near the base of the section	190

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
1. Covered to low water Paint Creek.	10
Total Ohio Shale is approximately	275+
Total section is approximately 360 feet thick	

SECTION 2

Tener Mountain Section

Nearly complete section of Ohio Shale, Bedford Shale, Berea Sandstone, and Sunbury Shale exposed for 5.1 miles in roadcuts along both sides of Ohio Highway 32 near Peebles, Franklin Township, Adams County, Ohio. Base of section is on northwest side of Ohio Highway 32 at its junction with Ohio Highway 73 (Jaybird quadrangle), where lowermost 26.5 feet were measured and described. Upper 215.9 feet of section ending at top of Ohio Shale were measured along east side of Ohio Highway 32, (Byington quadrangle). Incomplete exposures of Bedford Shale, Berea Sandstone and Sunbury Shale on west side of Ohio Highway 32 at its intersection with Union Hill Road, 1.15 miles northeast (Byington quadrangle). Section measured, described, and sampled using Jacob's staff, Abney level, aneroid barometer, and tape, and its radioactivity profile measured using scintillometer by R. C. Kepferle, P. E. Potter, Linda J. Provo, and Tom Yu, June 25 and 29, 1976

Mississippian (incomplete):	Thickness (feet)
Cuyahoga Formation (incomplete):	
38. Siltstone (single bed), weathers yellowish-gray (5Y 8/1); Zoophycos-like burrows on top; limonite stain along joint. Two sets of sole marks at 205° and 280°, with blunter ends toward these directions. Massive bedding, probably Ta interval of Bouma (1962).	1.3
37. Shale, greenish-gray (5G 6/1), locally blackish-red (5R 2/2) to grayish-red (5R 4/2) higher in unit. Rare, poorly defined siltstone beds, olive-gray (5Y 4/1) to light-brownish-gray (5YR 6/1) with limonitic stain	26.0
Total Cuyahoga Formation (incomplete). . . .	27.3+

Mississippian (continued):	Thickness (feet)
Sunbury Shale:	
36. Shale, black (N1) to grayish-black (N2), weathers medium light gray (N6) to yellowish gray (5Y 8/1) where stained with jarosite, grayish-brown (5Y 3/2) to dark yellowish-orange (10YR 6/6) where stained with limonite; fissile, laminated, brittle, no silt. Pyrite nodules, 4 cm., occur 4 feet below top and rarer, smaller (1-2 cm.) pyrite nodules, finely crystalline, lobate, flattened along bedding planes throughout rest of unit. Phosphate nodules, 2-3 cm., ovoid, with fossil core, at top of unit (sampled). Burrows, 4 mm. wide, along bedding planes, fairly straight, filled with light-olive-gray (5Y 6/1) mudstone. Vertical silica "dike" strikes 25° in ditch on west side of highway, 6-7 cm. wide, limonite-stained (sampled)	15.0
35. Siltstone, dark-gray (N3) where carbonaceous, grading to light-olive-gray (5Y 6/1), flecks of carbonaceous material and wispy dark streaks; abundant Lingula fragments. Distinct, irregular contact with less than 1 cm. of dark shale, like unit 36 with thin silt laminae less than 1 mm. thick and a few Lingula fragments (sampled).	0.05
34. Shale, grayish-black (N2), silty, laminated, pyrite, with very thin laminae of silt one or two grains thick. At top of unit is a trashy zone of Lingula fragments and conodonts (sampled). Basal contact sharp.	0.05
Total Sunbury Shale	15.1
Berea Sandstone:	
33. Sandstone, silty, medium-light-gray (N6) to light-olive-gray (5Y 6/1), weathers grayish-orange (10YR 7/4) to yellowish-gray (5Y 8/1); darker zones near top are pyritic; bed thickness increases upward from 0.7 foot to as much as 4 feet; at top is a 2-4 cm. pyrite bed	30.5
32. Sandstone and silty shale in equal amounts. Sandstone is like unit 33, except beds 0.1-0.2 foot thick. Upper bed surfaces are rippled; ripple crests strike 290-310°; wavelength is commonly 10 cm., wave height is commonly 1-2 cm.; cross laminae dip southwest in	

Mississippian (continued):	Thickness (feet)
Berea Sandstone (continued):	
lower parts of rippled beds and northeast in upper parts. Shale is greenish-gray (5GY 6/1, silty. Contacts sharp.	14.5
Total Berea Sandstone.	45.0
Bedford Shale:	
31. Shale (70 percent) and interbedded siltstone and very fine-grained sandstone (30 percent). Shale is greenish gray (5GY 6/1), silty, with some silt laminae. Siltstone and sandstone beds are less than 1 cm. thick, upper surfaces rippled and burrowed; complex burrow system on soles and load and flute casts (?). Amount of siltstone and sandstone increases in overlying units 32 and 33. Offset along basal contact of Bedford Shale 1.16 miles south along east side of Ohio Highway 32. .	20.0
30. Covered interval (thickness approximate)	60
Total Bedford Shale	80
Devonian:	
Ohio Shale (incomplete):	
29. Shale, dark-gray (N3) to brownish-black (5YR 2/1), weathers to very thin light-gray (N7) chips; brittle, fissile, subconchoidal fracture, tough when fresh, forms massive faces; no silt, pyritic; spores common throughout unit and increase in abundance upward; rare Lingula near upper contact. Uppermost 0.1 foot separated from main part of unit by 0.3 foot yellowish-brown (10YR 6/4) mudstone. Sampled at base and at 20 and 26 feet above base. Contact with underlying unit is sharp and slightly irregular.	61.1
Three Lick Bed:	
28. Shale, dark-greenish-gray (5GY 4/1) to greenish-gray (5GY 6/1), poorly laminated, soft, non-brittle, clayey; limonitic stain along bedding planes.	0.3
27. Shale, brownish-black (5YR 2/1), fissile, brittle, slightly silty, pyritic; rare spores.	0.2

Devonian (continued):

Ohio Shale (continued):

Three Lick Bed (continued):	Thickness (feet)
26. Shale, dark-greenish-gray (5GY 4/1) to greenish-gray (5GY 6/1), like unit 28. Sampled 0.7 foot below top	3.7
25. Shale, brownish-black (5YR 2/1), like unit 27	4.3
24. Shale, dark-greenish-gray (5GY 4/1) to greenish-gray (5GY 6/1), like unit 28.	0.2
23. Shale, brownish-black (5YR 2/1), like unit 27, slightly mottled. Sampled at base.	1.1
22. Shale, dark-greenish-gray (5GY 4/1) to greenish-gray (5GY 6/1), like unit 28; possible pyrite-filled burrows along bedding. Sampled 0.8 foot above base	2.2
21. Shale, brownish-black (5YR 2/1), like unit 27; abundant spores	3.0
20. Shale, dark-greenish-gray (5GY 4/1) to greenish-gray (5GY 6/1), like unit 28; abundant, tiny flecks of black carbonaceous matter.	0.2
19. Shale, brownish-black (5YR 2/1), like unit 27; 1 cm. clay shale parting 0.6 foot above base; rare spores. Sampled at 0.2 foot above base.	1.5
18. Shale, dark-greenish-gray (5GY 4/1) to greenish-gray (5GY 6/1), like unit 28. Sampled 0.5 foot above base.	4.4
Total Three Lick Bed	21.1

17. Shale, dark-gray (N3) to grayish-black (N2), weathers light gray (N7) to medium light gray (N6) chips, 1-2 cm; fissile, brittle, uniform, subconchoidal fracture, silty; numerous spores near base, decreasing in abundance upward; abundant flecks of black carbonaceous matter; few pyrite nodules, 2-3 cm., flattened along bedding planes in lower 3 feet of unit; pyritic zone 9 feet below top; two 0.1-foot thick, discontinuous cone-in-cone layers at 22 (sampled) and 33.5 feet below top. Unit weathers in ribbed fashion with ribs 0.5 foot thick separated by talus-covered slopes 0.2 to 0.5 foot thick.

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
Denser, more resistant bed at 40 feet above base. Sampled 6 and 43 feet above base	96.0
16. Shale, dark-greenish-gray (5GY 4/1), thinly laminated, poorly fissile, clayey, cohesive.	0.1
15. Shale, dark-gray (N3), fissile, brittle, fine; rare spores.	1.5
14. Shale, dark-greenish-gray (5GY 4/1), like unit 16. .	0.4
13. Shale, dark-gray (N3) to medium-dark-grey (N4), like unit 15. Contact with underlying gray shale sharp .	0.5
12. Shale, dark-greenish-gray (5GY 4/1), like unit 16. .	0.4
11. Shale, grayish-black (N2) to brownish-black (5YR 2/1), weathers to thin, small chips less than 1 cm. in diameter; laminated with laminae 1-2 mm. thick; poorly fissile, fine, pyritic; spores common to rare. . . .	1.1
10. Shale, greenish-gray (5GY 6/1) to dark-greenish-gray (GY 4/1), weathers to thin, fissile flakes; clayey to slightly silty; thinly laminated with laminae 1-2 mm. thick; flecks of black carbonaceous matter. Moderate-brown (5YR 4/4) iron-oxide stain along bedding. Interbedded with five thin, dark-gray (N3) shale beds at base and at 0.45-0.50, 1.1, 1.7, and 2.9 feet above base; contacts sharp. Upper 2 feet of this unit does not have dark-gray shale interbedded and is separated from lower 8.4 feet by a 0.6 foot zone of dark-gray shale with a thin (less than 5 mm.), silty, concretionary pyrite zone. Slightly sideritic concretionary zones, 0.5 foot thick, at 3.0, 4.0-4.5, and 7.5-8.0 feet above base; brittle, tough, dense, conchoidal fracture, weather dark yellowish orange (10YR 6/6). 2 cm.-thick cone-in-cone limestone layer 7.9 feet above base. In upper 2 feet, pyrite nodules are numerous, botryoidal, typically 1-2 cm. and up to 8 cm. long; flattened slightly along bedding, long axis parallels bedding; small pyrite-filled burrows (?) parallel to bedding. Sharp planar contact with underlying unit. Sampled 3 feet above base	11.0

Devonian (continued):

	Thickness (feet)
Ohio Shale (continued):	
9. Shale, brownish-black (5YR 3/1), slightly silty, thickly bedded, in beds 5-6 mm. thick, breaks along bedding with subconchoidal fracture, brittle, tough; 0.4 foot below top is a parting of greenish-gray (5GY 6/1) clay; abundant flecks of unidentifiable black carbonaceous debris, no spores, selenite rosettes along weathered bedding planes; about 1.0 foot below top are two fragments of coalified Callixylon (?) 1.2 feet long and 0.8 foot wide. . . .	6.0
8. Shale, grayish-black (N2) to brownish-black (5YR 2/1), weathers to thin chips, 3-4 cm., light-gray (N7) to medium-light-gray (N6); fissile, thinly laminated, brittle, subconchoidal fracture, slightly silty; where freshest, unit weathers into subround fragments up to 10 cm. across; rare pyrite nodules, 1-2 cm. in diameter; slightly pitted surface on some bedding planes. Abundant black Foerstia, lobate, especially conspicuous in weathered, lighter gray chips. Joints 3 feet apart strike 345° and dip 67° west. Sampled 1 foot above base and at top . . .	12.0
7. Shale, brownish-black (5YR 2/1) and olive-black (5Y 2/1), weathers medium light gray (N6) to light gray (N7) with pale-greenish-yellow (10Y 8/2) iron sulfate and dark-yellowish-orange (10YR 6/6) iron-oxide coatings; subconchoidal fracture, brittle, dense where fresh; spores absent to rare. Alternating massive and fissile-weathering beds in 0.5 to 0.8 foot couplets give outcrop a ribbed appearance; thin, brittle chips litter weathered slopes; sulphurous water seeps from near base of section	4.2
Total Ohio Shale in single exposure	215+
Section thickness in units 7 through 38 totals about 383 feet.	

Offset 4.1 miles to southwest on north side of Ohio Highway 32 near its junction with Ohio Highway 73 for description of basal 26.5 feet of section.

6. Covered; poor exposures of this interval along highway from Hackleshin Road to Ohio Highway 73, not measured.

Devonian (continued):

	Thickness (feet)
Ohio Shale (continued):	
5. Covered, with gravel cap to top of exposure; not included in section.	
4. Shale, light-brownish-gray (5YR 6/1) grading upward to greenish-gray (5GY 6/1); Lingula; fish scales (?); burrows filled with greenish-gray clay.	3.0
3. Shale, olive-black (5Y 2/1), weathers light-brownish-gray (5YR 6/1), light gray (N7), to yellowish-gray (5Y 8/1); silty; pyrite-cemented layer in basal 2 cm. and some pyrite as flattened discs 2 cm. in diameter along bedding planes; Tasmanites common	4.5
Total lower Ohio Shale (incomplete).	7.5
Olentangy Shale(?):	
2. Shale, greenish-gray (5G 6/1) to light-bluish-gray (5B 7/1); silty, non-calcareous; gray streak. 0.1 foot thick, approximately 7 feet above base; at base, pyrite layer, coarsely crystalline, 1-2 cm. thick with knobby, irregular upper surface contains fine, rounded quartz sand.	7.0
Total Olentangy Shale	7

Unconformity.

Silurian (incomplete):

Tymochtee Dolomite (incomplete):	
1. Dolomite, yellowish-gray (5Y 7/2), weathers grayish-orange (10YR 7/4); silt-sized grains, uniform; irregular bedding; some pyrite nodules, 2-3 cm.; calcareous at top	10.0+
Total Tymochtee Dolomite (incomplete).	10.0+
Total thickness of lower part of section . . .	24.5

NOTE: Unit 6 (covered interval) is poorly exposed along Ohio Highway 32 between Ohio Highway 73 and the Hackleshin Road. This part of the section in other roadcuts and railroad cuts along Ohio Highway 73 and Portsmouth Road, southeast of the measured composite section, consists of black, fissile shale and greenish-gray shale with large, subrounded calcareous concretions as large as 2 feet in diameter. The thickness of this interval is not known, but Calvert (1968) indicates that the Ohio Shale in this area is nearly 300 feet thick; thus, as much as 70 feet of section may be missing from this description.

SECTION 3

TYPE SECTION OF THREE LICK BED

Interstate 64 Section Near Morehead Interchange

Complete section of Sunbury Shale, Bedford Shale, and Ohio Shale exposed in two large roadcuts along Interstate Highway 64; base of section is on south side of highway, 1.35 miles east of Bath-Rowan County line, 1,150 feet FNL x 900 feet FWL Sec. 10-T-71, Rowan County, Kentucky (Farmers quadrangle), at bridge across I-64 at west end of cut. Upper 83 feet of complete section (units 14 - 19) are described from exposures on north side of Interstate Highway 64, 3.20 miles east of Bath-Rowan County line, 1,200 feet FNL x 550 feet FEL Sec. 5-T-72, Rowan County, Kentucky (Farmers quadrangle). Described and measured by Linda J. Provo, Michael D. Lewan, and R. C. Kepferle using hand level and tape, April 28, 1976.

	Thickness (feet)
Mississippian (incomplete):	
Borden Formation (incomplete):	
Henley Bed of Farmers Member (incomplete):	
19. Mudstone, greenish-gray (5GY 6/1), silty; hackly fracture, limonitic stain; grass and vetch cover upper part of exposure. Basal contact sharp.	1.0+
Sunbury Shale:	
18. Shale, black (N1), very slightly silty, fissile, brittle; weathers medium gray (N6) to yellowish gray (5Y 8/1); fresh pieces have subconchoidal fracture; pyrite nodules along bedding planes at 4.5 and 5.5 feet above base; no spores; possible vertical and horizontal lens-shaped burrows indicated by lighter zones 2 to 3 mm. wide in uppermost part; lag concentrate at base 5 mm. thick, contains numerous Lingula, a few conodonts, rare spores. Both upper and lower contacts must be excavated to be seen. Sampled at base	18.2
Total Sunbury Shale.	18.2
Bedford Shale:	
17. Mudstone, olive-gray (5Y 4/1), slightly calcareous; weathers light olive gray (5Y 6/1); limonite seam along bedding plane 4.4 feet above base	14.8

Mississippian (continued):	Thickness (feet)
Bedford Shale (continued):	
16. Shale, black (N1), fine, even-textured, little silt; some spores; limonitic coating on sharp upper and lower contacts.	0.05
15. Mudstone, greenish-gray (5GY 6/1), silty, slightly calcareous; semispheroidal fracture; Lingula at 1 cm. above base. Basal contact sharp.	0.2
Total Bedford Shale.	15.05
Devonian:	
Ohio Shale:	
14. Shale, brownish-black (5YR 2/1); fissile, brittle; weathers progressively from medium light gray (N6) surfaces to moderate yellowish-brown (10YR 5/6), dusky yellowish-brown (10YR 2/2) with olive cast, and light brown (5YR 5/6) to dark yellowish-orange (10YR 6/6); morphology of weathered, near-vertical cuts characterized by smooth-weathering faces interbedded with splintery fissile-weathering faces to give outcrop a ribbed appearance; typical thicknesses are 0.1 to 0.3 foot for smooth faces and 0.5 foot for splintery faces; upper 22 feet of unit less well exposed in a steep talus-littered slope with occasional ledges about 0.5 foot thick well exposed; highly altered cone-in-cone limestone layer 1 to 2 cm. thick at 5.2 feet above base; spores small and inconspicuous near top, increase in size and abundance toward base; Lingula found at top. Basal contact with grayish-green shale sharp; offset on this contact to south side of Interstate Highway 64 in Sec. 10-T-71 to west for description of underlying units. Here flattened, amoebiform phosphate nodules 10 to 15 cm. long were found 31 and 33 feet above base of unit and a trash zone 2 to 3 mm. thick, with Lingula, fish bones, conodonts and small phosphate pebbles were found in the float on the slope of this unit	48.8
Three Lick Bed:	
13. Shale, grayish-green (5GY 4/1), iron-stained; basal contact gradational into black shale over 0.1 foot interval.	1.5

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
Three Lick Bed (continued):	
12. Shale, olive-black (5Y 2/1), fissile; like unit 10; pyrite nodules in somewhat persistent zone about 1 foot above base; discontinuous cone-in-cone layer 1.9 feet above base, also observed at same horizon in roadcut to east. Basal contact sharp.	4.2
11. Shale, greenish-gray (5G 6/1), like unit 9.	0.9
10. Shale, olive-black (5Y 2/1), fissile; selenite rosettes on bedding planes; spores abundant; basal contact sharp	2.6
9. Shale, greenish-gray (5GY 5/1); secondary red (5YR 5/6) stain along bedding; basal 3-5 cm. burrowed, with burrows decreasing in abundance upward; Lingula at base; sharp basal contact.	2.3
Total Three Lick Bed	11.5
8. Shale, medium dark gray (N4) to medium-gray (N5); surface stained yellowish-brown; fissile; numerous spores on some bedding planes; discontinuous cone-in-cone layer attains maximum thickness of 0.2 foot about 5 feet below top of unit; pyrite nodules about 3 mm. thick concentrated along bedding plane about 22 feet above sharp basal contact	53.8
7. Shale, brownish-black (5YR 2/1); fissile; like unit 3; homogeneous; at top is a clay-shale seam, 1 cm. thick, which weathers light gray (N7); interlaminated with dark shale in couplets less than 1 mm. thick in 1-cm. interval below seam.	21.6
6. Interbedded light (60 percent) and dark (40 percent) shale. Light shale is greenish-gray (5GY 4/1) to light olive gray (5Y 6/1), argillaceous, micaceous, poorly fissile in 9 beds ranging from 0.2 to 1.5 feet thick; basal contacts sharp to gradational over 1 cm. Interbedded dark shale is olive black (5Y 2/1), in 8 beds 0.1 to 1.7 feet thick; well-preserved Foerstia common to abundant, some show lobate morphology; basal contacts sharp	8.3

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
5. Shale, brownish-black (5YR 2/1), fissile, brittle; weathers blocky and massive in lower two-thirds, less resistant in upper one-third of unit; pyrite occurs along bedding planes; conodonts rare; possible Foerstia? (algae) in upper 0.1 foot of unit; spores in basal 0.1 foot. Sampled at sharp basal contact	20.3
4. Shale, interbedded, light (70 percent) and dark (30 percent). Light shale is greenish-gray (5GY 6/1), in beds ranging from 0.2 to 0.5 foot thick; top of uppermost bed is burrowed. Dark shale is brownish-black (5Y 3/1), like underlying unit, in beds 0.1 to 0.3 foot thick	9.1
3. Shale, brownish-black (5YR 2/1), brittle, fissile, laminated, with abundant reddish-brown Tasmanites spores and some flakes of chitinous (?) material; pyrite nodules well developed along selected bedding planes; prominent horizon 2.6 feet below top of unit, contains elongate nodules 1 to 3 cm. thick and 3 to 4 cm. wide; another 1-mm.-thick layer occurs at sharp basal contact	5.1
2. Shale, light olive-gray (5Y 6/1), greenish-gray (5GY 6/1) to dark greenish-gray (5G 5/1); weathers light gray (N7) to yellowish gray (5Y 8/1), joints stained with limonite; clayey to slightly silty; spores rare; contains interbeds 2 to 3 cm. thick of brownish-black (5YR 2/1) to dark gray (N4) shale with poorly defined contacts at 1.1 feet, 2.7 feet, and 2.9 feet below top. Basal contact is sharp, locally marked by pyritic sandy layer 1 cm. thick, but obscure where pyrite layer is absent.	3.0
Total Ohio Shale.	181.5
Unit may be equivalent of Olentangy Shale.	
Unconformity.	
Silurian (incomplete):	
Crab Orchard Formation (partially exposed):	
1. Shale (85 percent) and dolomite (15 percent). Shale is olive-gray (5Y 5/1), clayey, dolomitic, poorly fissile; weathers to light gray (N7) thin flakes 1 to	

Thickness (feet)

Silurian (continued):

Crab Orchard Formation (continued):

2 cm. across and 2 mm. thick; in beds about 0.5 foot thick. Dolomite is light olive gray (5Y 6/1); weathers light brown (5YR 5/6) to moderate brown (5YR 4/4); silt-size grains; Chondrites-like burrows are mainly parallel to bedding, but a few are vertical in discontinuous thin beds and fairly continupus thicker beds up to 0.2 foot thick. Remaining part of Crab Orchard Formation not exposed below road level. . . . . 22.0+

Total thickness of section about 238 feet.

(Note: Reconnaissance hand-level measurement above unit 13 in the western roadcut encountered 50 feet of Ohio Shale to the base of the Bedford Shale; the Bedford was measured as 13.5 feet thick, and the lower 7 feet of the Sunbury Shale was exposed at the top of the cleared roadcut.)

SECTION 4

Mountain Parkway Section Near Clay City

Nearly complete section of New Albany Shale exposed in two large roadcuts and one quarry along Mountain Parkway in Powell County, Kentucky (Clay City Quadrangle). Upper 54 feet of section are described from cut on east side of Kentucky Highway 1057, south of bridge over Mountain Parkway, 1725 feet FNL x 575 feet FEL Sec. 25-Q-68; the underlying units (1-14) are described from a quarry on the north side of Kentucky Highway 15, 0.1 mile northwest of its junction with Kentucky Highways 11 and 82, and from the large roadcut 0.15 miles farther west; base of section is on north side of Mountain Parkway, 0.25 miles west of overpass at Clay City interchange (Exit 16), 925 feet FSL x 900 feet FWL Sec. 11-Q-67. Described and measured by R. C. Kepferle, Michael D. Lewan, J. B. Maynard, P. E. Potter, and Linda J. Provo using hand level and tape, May 20, 1976.

Thickness (feet)

Mississippian (incomplete):

Nancy Member of Borden Formation (incomplete):

23. Covered, to top of ridge overgrown by grass and small evergreen trees; not measured; contact with underlying unit is not exposed but is mapped at elevation 720+ feet (Simmons, 1967) and is believed to be near top of exposure, below.

Devonian (incomplete):	Thickness (feet)
New Albany Shale:	
22. Shale, dark gray (N3), slightly silty, fissile; basal contact marked by underlying phosphate nodules. . . .	4.7+
21. Shale, dark gray (N3), slightly silty, uniform, fissile; elongate, flattened phosphate nodules as much as 0.3 foot long and 0.1 foot thick occur randomly along bedding planes; irridescent limonitic coating on bedding planes; fish scales and unidentifiable parts, rare; spore Tasmanites, common; contact with underlying cone-in-cone limestone layer sharp. Sampled at top of unit.	24.0
20. Shale, brownish-black (5YR 2/1), silty, fissile; yellowish-gray (5YR 7/2) powdery, weathered coating on bedding planes; at top is continuous cone-in-cone limestone layer, 0.1 foot-thick, heavily stained with limonite; spores abundant. Contact with underlying unit sharp.	19.2
Three Lick Bed:	
19. Mudstone, medium-light gray (N6), silty; poorly laminated, hackly fracture; selenite crystals and limonitic stain on weathered surfaces; unit sampled at westernmost cut. Basal contact sharp.	0.7
18. Shale, dark gray (N3) to medium-dark gray (N4), well laminated, with laminae about 1 mm. thick; few Tasmanites; selenite rosettes and limonitic stain along bedding planes. Basal contact sharp.	2.7
17. Mudstone, medium-light gray (N6), like unit 18; sampled at westernmost cut. Basal contact sharp.	0.5
16. Shale, dark-gray (N3), like unit 17	1.7
15. Mudstone, medium-light gray (N6); like unit 18; base and top are gradational; sampled in westernmost cut. The alternation of gray mudstone and dark-gray shale imparts a ribbed appearance to the outcrops that includes units 18 to 14. Offset on this contact to quarry on north side of Kentucky Highway 15, 2.1 miles to northwest, in Sec. 11-Q-67 for description of the underlying unit	0.6
Total Three Lick Bed	6.2

Devonian (continued):	Thickness (feet)
New Albany Shale (continued):	
14. Shale, dark gray (N3), fissile, massive, uniform; interbedded with as many as six fairly continuous medium-gray (N5) to medium-dark-gray (N4) cone-in-cone limestone layers which are locally pyritic and are commonly less than 0.1 foot thick at base and top of unit and at 2.1, 7.3, 8.7, 12.2, 13.0, 14.3, 23.1, and 24.2 feet above base locally in this and adjacent exposure to west; cone-in-cone beds weather to limonite-stained light brown (5YR 5/6); lowest, highest, and bed 7.2 feet above base were sampled. Offset along contact to exposure 0.15 miles to west .	26.9
13. Shale, dark-gray (N3) to brownish-black (5YR 2/1); silty, well-laminated, with laminae 1-2 mm. thick; even fracture, tough; rare Tasmanites; poorly formed selenite rosettes and irregular masses of selenite common common along bedding planes and fractures, which are also stained with limonite and sulfate. . .	17.3
12. Covered at road; probably similar to underlying unit 10; section offset across Kentucky Highway 15 to south	2.4
11. Shale, brownish-black (5YR 2/1), silty; more fissile than underlying units; red-brown Tasmanites spores abundant; Foerstia prominent in weathered zone 4.1 feet above base (sampled); limonite and sulfate stain on bedding and joint planes	12.2
10. Covered; probably similar to unit 8; slope littered with thin, medium gray shale chips.	1.7
9. Shale, grayish-black (N2), fine silt; fissile; weathers to splintery fragments; pyritic; 3.6 feet below top of unit is a highly weathered zone 0.4 foot thick containing abundant spores and iron-sulfide nodules which have finely crystalline, rounded bases and which mushroom upward into coarser octahedral crystals, with bedding draped around crystals (this zone is also identifiable in the quarry exposure to the east); limonite and sulfate stain on joint faces; sampled 5.2 feet below top of unit.	10.0

Devonian (continued):	Thickness (feet)
New Albany Shale (continued):	
8. Light and dark shale interbedded in subequal amounts in about 20 couplets. Light shale is olive gray (5Y 4/1) to greenish gray (5GY 6/1) and medium gray (N5) in beds commonly 0.1 foot thick and as much as 1.0 foot thick; burrows (?) common to rare along bedding planes, some ramose and straight, others fainter and meandering; coaly material in one bed near middle of unit. Dark shale is brownish black (5YR 2/1), dark gray (N3) to grayish black (N2) in beds ranging in thickness from 0.1 to 1.5 feet; pyritic; fossils include sparse Tasmanites spores and conodonts, rare Lingula and, near top, Foerstia (?) and Zoophycos-like burrows. Boundaries between beds sharp to gradational over 1 to 2 cm.	10.4
7. Shale, grayish-black (N2), fissile, like unit 4. . .	1.3
6. Covered, at first major bench above base; slope littered with light gray shale chips	2.0
5. Shale, grayish-black (N2), fissile, brittle, with subconchoidal fracture where fresh; weathers to light-gray (N7) chips which litter slopes; pyrite in irregular concentrations along bedding planes; some Tasmanites and Lingula; heavily stained with limonite and sulfate; basal contact gradational over 0.1 foot	4.0
4. Dolomudstone, olive gray (5Y 4/1), weathers to rounded prisms less than 1 cm. on a side; clayey; lower contact sharp.	0.9
3. Interbedded shale and dolomudstone in descending order: shale, 1.9 feet; dolomite, 1.0 foot; shale, 1.1 feet; dolomite, 0.3 foot; shale, 0.2 foot; dolomite, 0.8 foot; shale, 0.3 foot (basal shale sampled). Shale is dark gray (N3), slightly silty, fissile, brittle, well-laminated, with laminae about 2 mm. thick; abundant Tasmanites spores; burrows (?) are gently curved, 0.5 to 1 cm. wide, locally pyritic, common on bedding planes. Dolosiltstone is olive gray (5Y 4/1), bioturbated. Basal contact is gradational	5.6

Devonian (continued):

	Thickness (feet)
New Albany Shale (continued):	
2. Shale, olive gray (5Y 4/1), silty, dolomitic near base; weathers to very light gray (N8), poorly fissile chips less than 1 cm. across; ribbed weathering pattern well-developed in upper 3 feet of unit in couplets 0.3 to 0.4 foot thick; blocky weathering zone occurs 2.5 feet above base; Tasmanites common; sampled 2.1 feet above base. Basal contact is sharp, unconformable, irregular, with local relief of about 0.1 foot.	7.8
Total New Albany Shale (see note).	156.6

Unconformity:

Boyle Dolomite (incomplete):	
1. Dolomite, medium-light-gray (N6), silt-sized grains; weathers to grayish-orange (10YR 7/4); dense, with some wavy bedding and stylolites; chert nodules, medium-gray (N5), irregular to amoebiform, as much as 0.3 foot thick and 2 feet long; discontinuous clay parting 1.5 feet below top; calcite, pyrite, and sphalerite occur as irregular blebs in upper 0.5 foot, but appear to be unrelated to concentration of burrows (?) in same interval and which are parallel to bedding and a few centimeters wide; crinoids and other fossils weather out forming a pitted, irregular surface, suggesting that this unit may be a dolomitized limestone. Unit appears as single massive bed; remaining Boyle not exposed at road level in this section	4.4
Total thickness of section is about.	161

(Note: In the westernmost cut the inclusive interval between the lowest and highest greenish-gray mudstone beds (correlative with units 15 through 19 in the quarry part of the section) is 5.8 feet. Above this interval, a thickness of 21 feet of black shale is exposed on the steep face of the cut, and the uppermost 25 feet are covered. The uppermost 4 feet of the ridge is capped by the Nancy Member of the Borden Formation. Thus, the total thickness of the New Albany Shale at the westernmost section is about 152 feet.)

SECTION 5

Berea, Kentucky, Section

Nearly complete section of New Albany Shale exposed in series of cuts on east side of Interstate Highway 75 at and south of exchange and crossing of Kentucky Highway 21 west of Berea, Madison County, Kentucky. Top of section is south of overpass, 575 feet FNL and 600 feet FWL of Sec. 7-M-63; base of section is along entrance ramp to the northbound lanes of Interstate Highway 75 (Berea quadrangle). Section measured, described, and sampled, and its radioactivity profile measured using Jacob's staff, tape, Abney level, and scintillometer by R. C. Kepferle and Paul Edwin Potter, July 9, 1976.

	Thickness (feet)
Quaternary (?)	
15. Soil, olive-gray (5Y 4/1) to yellowish-gray (5Y 8/1), containing, near base, quartzite pebbles, siliceous geodes, and phosphatic nodules derived from nearby and underlying bedrock units; weathers to grassy flat. Erosional contact.	5+
Devonian:	
New Albany Shale (incomplete):	
14. Shale, brownish-black (5YR 2/1), weathers light gray (N7), with some iron oxide and sulfide stain on fractures and bedding planes along with rosettes and prisms of selenite 3 to 5 mm. long; silt in discontinuous laminae 1 to 2 grains thick; pyrite in discoidal concretions and disseminated grains; phosphate in nodules which are round to amoebiform, 2 to 3 cm. thick, elongate, some more than 13 cm. across, brownish-gray (5YR 4/1) and brownish-black (5YR 2/1), weather yellowish-gray (5Y 8/1) on surface, with earthy luster and rough fracture; fossils include Tasmanites spores and a vitrain layer 3 mm. thick 5 feet above base. Top at or near contact with grayish-green shale of basal Borden Formation seen in outcrop less than 1 mile to the west. Basal contact placed at lowest phosphate nodule.	9
13. Shale, brownish-black (5YR 2/1) to grayish-black (N2), like unit above, except contains no phosphate nodules; 8 feet above base is zone of pyrite concretions 0.1 foot in diameter and 0.5 cm. thick, concentrated along bedding planes; shale weathers to fissile, brittle flakes and plates as much as 0.4 foot in diameter; Tasmanites abundant; possible fish scale, 1 mm. across,	

Devonian (continued):	Thickness (feet)
New Albany Shale (continued):	
near top of unit; silt laminae increase in abundance downward; tough and dense, with subconchoidal fracture where fresh. Sharp basal contact.	18
Three Lick Bed:	
12. Shale, greenish-gray (5GY 5/1-4/1), weathers yellowish-gray (5Y 8/1), clayey, subconchoidal fracture on joints and partings coated with limonite and sulfate stain. Sharp contact with underlying unit.	0.8
11. Shale, black (N1) to grayish-black (N2) and brownish-black (5YR 2/1); weathers light gray (N7), with iron oxide and sulfate stain; silt laminae 1 to 2 grains thick, commonly about 5 mm. to 1 cm. apart; brittle flakes litter outcrop; burrowed in upper 0.1 foot, burrows filled with greenish shale from overlying unit?; discontinuous cone-in-cone limestone layer, dark-gray (N5), 0.1 thick, about 0.6 below top (sampled); basal contact sharp.	1.2
10. Shale, greenish-gray (5GY 5/1 to 4/1) like unit 12; basal contact sharp	0.4
9. Shale, brownish-black (5YR 2/1) like unit 11; fish scale(?) 0.3 above base; Tasmanites sparse; upper 0.1 burrowed; pyrite up to 2 mm. in scattered blebs; basal contact sharp	0.9
8. Shale, greenish-gray (5GY 5/1) like unit 12; sharp contact with underlying unit. Offset north along contact to first cut south of interchange; and in borrow pit east of cut.	0.2
Total Three Lick Bed	3.5
7. Shale, black (N1), grayish-black (N2), and brownish-black (5YR 2/1); slightly silty; some silt laminae 1 to 2 grains thick about 5 mm. apart; burrowed in upper 0.2 feet; burrows are gently curving, burrow-fill is medium dark gray (N4); as much as 0.5 cm. wide along bedding planes; Tasmanites sparse to abundant; some scattered black organic shreds; pyritic; slightly more resistant-weathering rib at about 20 feet above base (near base of cut); in upper 15 feet is rhythmic alternation of massive- and	

Devonian (continued):	Thickness (feet)
New Albany Shale (continued):	
fissile-weathering shale in sets 0.5 foot thick that impart ribbed appearance to otherwise littered slope. Poorly preserved Foerstia in 2.5 feet thick zone 8.9 fhet above base of unit; weathered chips typically have slight depressions on surfaces, where Foerstia have weathered out. All but lower 10 feet described up slope from middle light pole of north cut; basal 10' described from borrow pit to east	37
6. Interbedded light (60 percent) and dark shale. Light shale is greenish-gray (5Y 6/1) in 7 beds decreasing downward in thickness from 2.4 to 0.1 feet; thickest gray shale contains 4 thin brown-shale streaks. Dark shale is brownish-black (5YR 2/1) to dusky brown (5YR 2/2); silty in thin laminae in 6 beds 1.3 to 0.1 feet thick; lowest dark shale burrowed (dug this section out)	5.6
5. Shale, black (0.1+ foot), and covered . . . . . Offset to north-bound entrance ramp to I-75	16
4. Dolomudstone, greenish-gray (5G 6/1), weathers to yellowish-gray (5Y 8/1) prisms with spheroidal sides. Basal contact sharp. (Top covered in grass on west side; may be black shale recoverable across to west).	2.7+
3. Organic dolomitic mudstone, olive-black (5Y 2/1), weathers yellowish-gray (5Y 8/1); laminated; base marked by 0.05-thick rippled(?) sandy layer. Basal contact sharp	1.7
2. Dolomitic mudstone, laminated, olive-black (5Y 2/1); base sharp, irregular, relief of about 0.1 foot; weathers yellowish-gray (5Y 8/1).	1.2
Total New Albany Shale	94.7

Unconformity.

Boyle Dolomite (incomplete):

1. Dolomitic limestone, dark gray (N3), olive gray (5Y 4/1), to light-olive-gray (5Y 6/1); weathers yellowish-brown (5YR 5/4) to dark yellowish-orange (10YR 6/6); locally conglomeratic, with lighter olive pebbles 1 to 6 cm. long in a darker matrix; scattered white calcite-filled pockets and massive chert in

Devonian (continued): Thickness (feet)

Boyle Dolomite (continued):
some beds; bed thickness 0.9 to 2.5 feet, accentuated by weathering along stylolitic bedding planes. Base not exposed . . . . . 9.2+

Total thickness of section, approximate. . . . 109

(Note: The slopes of the Interstate cuts lie at about 30° and are mainly mantled by a thin talus which can be removed by some trenching with mattock or shovel. The uppermost part of the New Albany Shale is well exposed about 1 mile west of the southern cut. There the shale is overlain by about 0.6 foot of brownish-gray to olive-gray shale, about 0.05 foot of black shale and then by the greenish-gray shale of the basal Borden.)

SECTION 6

Big Clifty Creek Section

Complete section of Chattanooga Shale exposed in small unnamed tributary to Big Clifty Creek and along Ringgold Road, 4.1 miles northwest of its junction with Old Kentucky Highway 80 at West Somerset, Pulaski County, Kentucky (Delmer quadrangle). Base of section is in unnamed tributary, 2,850 feet FSL x 2,400 feet FEL of Sec. 19-H-58; top of Chattanooga Shale is along unpaved road, 3,000 feet FSL x 2,425 feet FWL of Sec. 19-H-58. Section measured, described, and sampled using Jacob's staff, Abney level, and tape and its radioactivity profile measured using scintillation counter by R. C. Kepferle, P. E. Potter, and Linda J. Provo, August 3, 1976.

Mississippian (incomplete): Thickness (feet)

Borden Formation (incomplete):

Nancy Member (incomplete):
7. Shale, greenish-gray (5G 5/1), weathers light olive gray (5Y 7/1) to greenish-gray (5G 7/1); silty; rounded phosphate nodules along bedding planes approximately 1.4 and 2.8 feet above base, with glauconite around nodules . . . . . 15+

Total Nancy Member (incomplete) . . . . . 15+

Devonian (incomplete):	Thickness (feet)
Chattanooga Shale:	
6. Shale, brownish-black (5YR 2/1) to olive-black (5Y 2/1), weathers to light gray (N7) plates and chips; bedding planes and joints coated with sulfates of iron; Tasmanites common; abundant olive-gray (5Y 4/1) phosphate nodules, weather gradationally to chalky white, earthy luster, ovoid and elongate or amoebiform, typically 3-5 cm. thick and up to 1 foot long, somewhat flattened along bedding planes, bedding contorted over nodules; base of unit is at lowest occurrence of phosphate nodules; silica "dike", 2 cm. wide, vertical, geodiform, extends 15 feet laterally in ditch along unpaved road and 3 feet vertically into overlying unit. Contact with overlying Nancy Member is abrupt; a 0.2-foot-thick zone of phosphate nodules (sampled) in glauconite-stained mudstone (possibly equivalent to Maury Formation) occurs at top of this unit.	7.0
5. Shale, brownish-black (5YR 2/1), like unit 3.	7.0
Three Lick Bed:	
4. Mudstone and shale, interbedded. Mudstone is olive gray (5Y 4/1), weathers moderate brown (5YR 4/4); clayey, pyritic; in three beds, less than 0.1 foot thick, occurring between 32.7 and 35 feet above base of section. Shale is brownish-black (5YR 2/1), like unit 3, with Tasmanites and sparse Lingula; burrowed immediately below mudstone beds; burrows curved, smooth-sided, up to 1 cm. wide, filled with light-brownish-gray clay (5YR 6/1), decrease in abundance upward to gray shale.	2.3
Total Three Lick Bed.	2.3
3. Shale, olive-black (5Y 2/1), weathers to medium-light-gray (N6) fissile chips and plates; pyrite in burrows in basal 0.5 foot and as stellate nodes which disrupt bedding and stand in relief on bedding planes, abundant pyrite as cubes and accretions at 24 to 26 feet above base with abundant lanceolate fish scales(?); Lingula common to abundant to 3.5 feet above base (oriented sample at 3.0 feet above base), long axes oriented at 206°, 283°, 291°, 300°, 301°, 304°, and 323°; thin clay shale seams, yellowish-brown (10YR 5/2), weathering yellowish-gray (5Y 8/1) and slightly recessed, less than 0.1 foot thick, occur 5.3, 15.8,	

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
16.7, and 17.7 feet above base; Tasmanites rare to abundant; rounded, medium-sized grains (20-30%) occur near base of unit; weathered outcrop has ribbed appearance due to alternating resistant and nonresistant beds in couplets 0.3 foot thick. Offset along bedding plane 5 feet below top to tributary to east. Basal contact sharp, paraconformable.	31.7
2. Sandstone, Duffin layer, olive-black (5Y 2/1) to brownish-black (wet, 5YR 2/1), weathers yellowish-gray (5Y 7/2) to moderate yellowish-brown (10YR 5/4); sand grains medium-sized, well-rounded, frosted; phosphatic, dolomitic; basal 0.2 foot contains phosphate pebbles 2-3 cm. wide which stand out in relief; pyrite as nodules 2 cm. wide near top; conodonts and fish(?) remains observed. Contact with underlying unit, disconformable (sampled)	0.9
Total Chattanooga Shale[1/]	48.9
Unconformity.	
Boyle Limestone (incomplete):	
1. Dolomite, olive-gray (wet, 5Y 4/1) weathers medium light gray (N6) to light gray (N7), limy, medium-grained, pyritic, few glauconite grains; fluted- and rounded-weathering beds 0.6-0.7 foot thick; 1.3 feet below top is 0.5-foot-thick bed of chert, mottled yellowish-gray (5Y 7/2) and olive-gray (5Y 4/1); weathers moderate brown (5Y 4/4) to dusky red (5R 3/4), iron oxide stain; dolomite contains solitary corals and brachiopods, locally calcite-filled. Base covered. . .	2.6
Total Boyle Limestone (incomplete).	2.6+
Total thickness of section, approximate	67

1/ NOTE: Compares with 47.4 feet of Chattanooga Shale measured by Hass (156, p. 27) at the same locality (Conant and Swanson, 1961, loc. 6).

SECTION 7

Creelsboro Section

Complete section of Chattanooga Shale along east side of Kentucky Highway 379 and in gulley along old road east of Highway 379, 2.9 miles west of Creelsboro, Russell County, Kentucky (Creelsboro quadrangle). Base of measured section is 1,900 feet FNL x 2,225 FEL in Carter coordinate, Sec. 15-E-52. Section measured and described using Jacob's staff, Abney level, and tape and its radioactivity profile measured using scintillation counter by R. C. Kepferle, P. E. Potter, and Linda J. Provo, August 3, 1976.

	Thickness (feet)
Mississippian (incomplete):	
Ft. Payne Formation (incomplete):	
12. Mudstone, greenish-gray (5GY 6/1), silty, glauconitic	5.0+
11. Mudstone, olive-gray (5Y 4/1), shaly.	0.2
Total Ft. Payne Formation (incomplete). . . .	5.2+
Devonian:	
Chattanooga Shale:	
10. Shale, brownish-black (5YR 2/1), petroliferous odor, abundant pyrite; contact with overlying Ft. Payne Formation is sharp and conformable.	0.4
9. Phosphatic nodules, concentrated in layer	0.1
8. Shale, brownish-black (5YR 2/1), slightly silty, slightly pyritic, weathers to medium-light-gray fissile flakes and chips; phosphate nodules occur 4.4 feet above base and extend to top with long axes oriented at 183°, 188°, 190°, 193°, 200°, 207°, and 215°.	15.9
7. Shale and mudstone. Shale is brownish-black (5YR 2/1), like unit 6, and burrowed. Mudstone occurs as three very thin seams, less than 1 cm. thick; unit possibly equivalent to Three Lick Bed.	1.7

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
6. Shale, brownish-black (5YR 2/1), weathers to medium-light-gray (N6) fissile flakes and chips; slightly silty with a few silt laminae one or two grains thick; slightly pyritic; Tasmanites common, and show upward increase in abundance; unit forms distinct, massive face; at 4.0 feet above base is a light-brown (5YR 5/6) clay parting 1 cm. thick; discontinuous dolomitic and pyritic layer, 0.1 foot thick, occurs 8.4 feet above base of unit.	13.1
5. Mudstone (70 percent) and shale (30 percent). Mudstone is brownish black (wet, 5YR 2/1) to medium dark gray (dry, N4), occasionally mottled with burrows parallel to bedding; beds range from 0.1 to 0.8 foot in thickness. Shale is brownish black (5YR 2/1), pyritic; contains Tasmanites, a few clay partings, and burrows; upper 0.2 foot is a "varved" bed of black shale and silt laminae 1 mm. thick.	4.2
4. Shale, black (wet, N1) to brownish-black (5YR 2/1), weathers to medium-gray (N5) to light gray (N7) thin, fissile flakes and plates; strong petroliferous odor from freshly broken surface; pyrite in stellate nodes; abundant conodonts on bedding plane near top of unit; burrowed along bedding planes near base; discontinuous conglomerate 0.2 above base, 0.1 foot thick, contains phosphate pebbles and bone fragments in sandy matrix. Basal contact sharp	3.5
Total Chattanooga Shale	38.9
Unconformity.	
Kiddville (?) Bed:	
3. Chert-pebble conglomerate in medium-grained, poorly sorted, well-rounded, sand matrix; iron-stained, discontinuous	0-0.5
Boyle (?) Limestone:	
2. Limestone residuum of silt and clay weathered and oxidized to moderate brown (5YR 4/4) to dark yellowish-brown (10YR 4/2); identifiable by chert content and position; chert occurs in three fairly continuous layers of olive-gray (5Y 4/1) to yellowish-gray (5Y 8/1),locally banded and mottled irregular nodules, which range in thickness from 0.2 foot to over 1.0 foot.	2-3.0
Total Boyle (?) Limestone residuum.	2-3.0

	Thickness (feet)
Unconformity.	
Ordovician (incomplete):	
Cumberland Formation (incomplete):	
1. Limestone, olive-gray (wet, 5Y 4/1), light-gray (dry, N7), weathers to light olive gray (5Y 7/1) to yellowish-gray (5Y 8/1); silt-sized grains; sparse glauconite; uniform, laminated; semi-conchoidal fracture; unfossiliferous except as burrows indicated by slight mottling; upper contact abrupt and uneven with relief as great as 1 foot in 10-feet-wide exposure	3.0+
Total Cumberland Formation (incomplete) . . .	3.0+
Total section, about.	50

Note: Complete section occurs along highway at 1900 feet FNL x 2,225 feet FEL of Sec. 15-E-52 and extends to gulley beside highway; top is not clearly exposed in gulley, but is well-defined. Orientations of phosphate nodules were taken from gulley exposure. Description of units 7 through 12 was made along main highway cut, a few hundred feet north, where exposures were better.

SECTION 8

Pleasant Grove Section

Complete section of Chattanooga Shale exposed in cut on north side of parking lot at Pleasant Grove Recreation Area of Dale Hollow Lake, 3.75 miles northeast of Tennessee Highway 53 bridge over Obey River at Celina, Clay County, Tennessee (Dale Hollow Dam quadrangle). Base of section is located 1,675 feet FNL x 150 feet FWL in Carter coordinate, Sec. 19-A-49E. Section measured and described using Jacob's staff, Abney level, and tape and its radioactivity profile measured using scintillation counter by R. C. Kepferle, P. E. Potter, and Linda J. Provo, August 4, 1976.

Mississippian (incomplete):	Thickness (feet)
Ft. Payne Formation (incomplete):	
11. Limestone (grainstone), medium-light-gray (N6), weathers to yellowish-gray (5Y 8/1); coarse-grained, crinoidal, stylolitic bedding, dolomitic and glauconitic in basal 0.3 foot; silicified in discontinuous bands of chert up to 0.3 foot thick and less than 1.0 foot apart; chert is medium light	

Mississippian (continued):	Thickness (feet)
Ft. Payne Formation (continued):	
gray (N6), weathers light gray (N7); basal contact erosional and disconformable. Overlying this 9-foot-thick unit are a mudstone bank (10 feet), crinoidal packstone (2 feet), and greenish-gray shale interbedded with thin dolomitic and cherty wackestones (16 feet)	37.0+
Total Ft. Payne Formation (incomplete). . . .	37+
Maury Shale:	
10. Phosphatic nodules in matrix of yellowish-gray (5Y 7/2) shale. Nodules are spherical to elongate and oriented at 117°, 121°, 124°, 134°, 139°, 146°, 170°, 203°, and 218°.	0.6
Total Maury Shale	0.6
Devonian (?):	
Chattanooga Shale:	
9. Shale, grayish-black (N2), weathers dark greenish-gray (5GY 4/1); occasional silt laminae; phosphate pebbles abundant in upper 0.2 foot; slightly pyritic with fairly continuous zone of 1-3 cm. pyrite nodules about 0.3 foot above base and scattered throughout; translucent, white conodonts common; sparse Lingula about 1.0 foot below top.	5.3
8. Shale, like unit 9. In this unit occur three burrowed zones, 2 cm. thick, at base, 0.1 foot above, and at top; burrows are 2-3 mm. wide, with dusky yellow (5Y 6/4) fill, and some vertical burrows extend downward into underlying black shale as much as 0.1 foot; basal burrowed zone characterized by greater abundance of and smaller size of burrows; probable correlative of Three Lick Bed	0.7
7. Shale, grayish-black (N2), like unit 9, with silty blebs (burrows?); base is marked by lowest occurrence of phosphate nodules.	4.4
6. Shale, grayish-black (N2), like unit 9, several thin pyrite seams and silt laminae; wood fragments oriented at 72° and 104°, 3.8 feet above base; 2.8 feet above base is a zone of elongate, 1-2 mm. tetragonal(?) crystals and crystal casts (sampled).	5.1

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
5. Burrowed zone, with burrows not well-defined.	0.4
4. Shale, black (N1), dense.	0.7
3. Shale, olive-black (5Y 2/1)	0.4
Total Chattanooga Shale	17.0
Unconformity.	
Boyle (?) Dolomite (incomplete):	
2. Limestone layer, pyritic, glauconitic	0.1
1. Dolomite, olive-gray (5Y 5/1), weathers light brown (5YR 5/6); cherty; silicified brachiopods stand out in relief	0.7+
Total Boyle (?) Dolomite (incomplete).	0.7+
Total section, about	55

This section is near section 16 of Conant and Swanson (1961, pl. 1), where 16.2 feet of shale are assigned to the Gassaway Member (Conant and Swanson, 1961, pl. 12). Thus, unit 3 above may correlate with the Dowelltown Member to the south.

SECTION 9

Flat Gap Road Section

Incomplete section of Chattanooga Shale and Grainger Formation exposed for 0.55 mile in roadcuts and creek beds along northeastern side of Tennessee Highway 31 (Flat Gap Road); top of Chattanooga Shale is located 4.25 miles north of junction of U.S. Highway 11W and Tennessee Highway 31 at Mooresburg, Hawkins County, Tennessee (Lee Valley quadrangle), 2,475 feet FSL x 2,875 feet FWL in Carter Coordinate, Sec. 24-1S-76E. Section measured, described, and sampled, and its radioactivity profile measured using Jacob's staff, Abney level, tape, compass, and scintillation counter by R. C. Kepferle, P. E. Potter, and Linda J. Provo, August 5, 1976.

Mississippian (incomplete): Thickness (feet)

Grainger Formation (incomplete):

Basal siltstone member (incomplete):

27. Interbedded siltstone (90 percent) and shale (10 percent). Siltstone is olive-gray (5Y 5/1), weathers dark yellowish-orange (10YR 6/6), uniform micaceous, noncalcareous; beds with sharp, planar bases; bed thickness increases upward from 0.1-0.3 foot at base to as much as 1.4 feet at 6 feet above base; possible Bouma sequences T_{abc} in some beds; lumpy sole marks and low-relief flute marks rare, oriented at 207° with blunt end toward northeast. Shale is olive-gray (5Y 4/1), silty, with grain size fining upward, poorly laminated, with thin elongate and flattened siderite nodules in fossiliferous beds commonly less than 0.3 foot thick. Basal parts of shale beds may represent T_e in Bouma (1962) sequence. Strike, 85°; dip, 26°S . . . . . 10+

Total Grainger Formation (incomplete) . . . . 10+

Devonian (incomplete):

Chattanooga Shale (incomplete):

26. Shale (90 percent) and siltstone (10 percent). Shale is medium dark gray (N4) with olive-gray cast, weathers medium light gray (N6) to light gray (N7); thinly laminated, noncalcareous; 50 feet below top shale is medium dark gray (dry, N4) to olive-black (wet, 5Y 2/1), pyritic, weathers subconchoidally and to small splinter; rare, noncalcareous nodules with limonitic crust, 2 feet long and 0.2 foot thick, along some bedding planes; bedding cut by joints and fractures.

    Siltstone is olive-gray (wet, 5Y 4/1) and medium light gray (dry, N6), weathers light gray (N7) with moderate yellowish-brown (10YR 5/4) limonitic stain, micaceous, pyritic, with fine specks of disseminated organic (?) debris; laminated, with T_{ab} Bouma (1962) sequences in beds commonly less than 0.2 foot thick, slightly graded; in upper part of unit sole marks include flute casts at 244° with blunt end toward east; siltstone beds increase in abundance upward in unit, with a bundle of siltstone beds less than 2 feet thick occurring 3 to 5 feet below top of unit. Discontinuous clay ironstone nodules, 2-3 cm. thick occur throughout unit. Beds strike 68°, dip 26°S. 90

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
25. Covered interval between end of highway cut and creek bed to northeast.	40
24. Shale, brownish-black (dry, 5YR 2/1) to black (wet, N1), weathers light gray (N7), slightly silty, pyritic, rare Tasmanites, and fish scale (?) fragments; joints coated with moderate reddish-brown (10R 4/6) limonitic material; exposed in stream east of culvert, where beds strike 95°, dip 30°S. Sampled about 1 foot below top.	6
23. Covered interval along road to north, probably shale like unit 24.	20
22. Shale, like unit 24, highly weathered exposure in farm lane east of Tennessee Highway 33 about 50 feet from road.	5+
21. Siltstone, very light olive-gray (5Y 7/1), muddy; limonite-stained joints; sharp contact with overlying shale; strike 78°; dip 29°S	3
20. Covered	35
19. Siltstone, light olive-gray (5Y 6/1), weathers yellowish-gray (5Y 7/1), noncalcareous, coarse-silt-sized grains, limonitic stain on weathered surfaces; bedding irregular and disrupted, suggesting burrowing; dark, clayey laminae are olive-gray (5Y 4/1); bedding thins and grain-size fines toward base of exposure, grading into siltstone interbedded with silty shale containing discontinuous clay ironstone nodules. Exposure, opposite Gordon home, weathers to elongate plates and chips with irregular, lumpy surfaces.	25
18. Covered; projected along road from base of overlying unit.	105
17. Siltstone, medium light gray (N6) to medium dark gray (N4) when dry, olive-gray (5Y 4/1) when wet; pyritic, burrowed, somewhat laminated, parting surfaces commonly less than 0.1 foot thick; steeply dipping fault plane bounds lower limit of unit. . . .	8
Fault.	

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
16. Siltstone, like unit 17, in a thinning-upward cycle in which beds in upper half part along muddy layers less than 1 cm. thick; bedding surfaces burrowed, with curly, meandering trace fossils (Scalarituba missouriensis); lower half of unit is massive-weathering with slickensided surfaces. Wood fragment, 10 cm. long, oriented at 282°. Strike 85°, dip 31°S.	13±2
15. Siltstone, like unit 17, in a thinning upward sequence in which basal 4 feet are massive with slickensided face and upper 3 feet are shaly-weathering owing to laminae of darker, argillaceous material; burrowed.	7
14. Siltstone, light gray (N7) with interlaminated medium dark gray (N4) clayey silt, ripple-cross-laminated in massive, blocky-weathering beds; sole marks; burrows near tops of beds, medium-dark gray (N4) to olive-black (5Y 2/1) argillaceous and carbonaceous partings about 0.3 foot thick. Basal 10-12 feet is more carbonaceous and weathers to thin plates and fissile chips. As a whole, unit 14 is a thickening upward sequence interrupted by two or three platy-weathering zones less than a foot thick.	45
13. Deformed zone. Shale and siltstone contorted; likely that disturbance is associated with shalier portions of this zone	20
12. Siltstone (80 percent) and shale (20 percent). Siltstone is medium gray (N5) to light olive-gray (5Y 6/1), limonitic weathering stain, micaceous along bedding planes; planar lamination common, ripple lamination less common, T_{ab} and possible T_{abc} sequences of Bouma (1962); maximum bed thickness 2 feet. Shale is medium gray (N5) to olive-gray (5Y 4/1); shaly-weathering ledge, 1.2 feet thick at base, vitrain layer at top. Unit 12 is a sequence in which beds thicken toward middle of unit from lower and upper boundaries; two thinning upward cycles eash about 10 feet thick occur in basal 20 feet.	50

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
11. Shale and siltstone interlaminated in subequal amounts (90 percent), and mudstone (10 percent). Siltstone is medium gray (N5) to light olive-gray (5Y 6/1) in beds less than 1 cm. thick. Mudstone is dark greenish-gray (5GY 6/1), weathers yellowish-gray (5Y 8/1), silty, micaceous, beds occur 2.1, 4.9, 10.2, 15.6, 16.2, 16.8, 17.3, 18.7, 20.1, and 20.4 feet above base of unit. Basal and upper contacts of unit sharp; basal 0.2 foot is olive-black (5Y 2/1) shale.	21
10. Shale and interlaminated siltstone, like unit 11 but less resistant and less carbonaceous. Silt laminae are medium gray (N5) and are typically less than 2 mm. thick, rarely in beds up to 2 cm. thick. Clay laminae are dark gray (N3) and less than 1 mm. thick. Two greenish-gray (5GY 6/1) mudstone and shale beds, 0.1 foot thick, occur at 31 and 37 feet above base. Near base, unit is shalier and pale yellowish-brown (5YR 6/2), weathers light brown (5YR 6/4). Foerstia (sampled) common to abundant in zone, 43 feet thick, beginning 13 feet above base	57
9. Covered; offset to creek bed to northeast	97
8. Mudstone with interbedded siltstone exposed in creek. Mudstone is olive-gray (5Y 7/1), slightly silty, in beds 0.1 to 0.2 foot thick. Siltstone is grayish-orange (10YR 7/4), with limonitic stain, planar lamination; evenly bedded with beds lensing locally	1+
7. Shale, brownish-black (5YR 2/1), fissile, brittle, with silty laminae one or two grains thick; unidentifiable black (fish part?) debris and conodonts; limonite-stained joints and parting surface; sampled.	1.5
6. Clay mudstone, like unit 8.	0.1
5. Shale, brownish-black (5YR 2/1), like unit 7.	0.5
4. Mudstone, olive-gray (5YR 4/1) to dusky brown (5YR 2/2), slightly silty	0.3

Devonian (continued):	Thickness (feet)
Chattanooga Shale (continued):	
3. Shale, brownish-black (5YR 2/1), like unit 7, rare, black spores; dip 40°	11
2. Covered	90
1. Exposure at dip slope opposite green dumpster. Shale, like unit 7, spores abundant; interbedded at base with greenish-gray mudstone. Dip 37°	10+
Total Chattanooga Shale (incomplete).	761.4
Total section, about.	771

[Note: Units 22 through 26 may be equivalent to Big Stone Gap Member as used by Hasson (1973, p. 21).]

SECTION 10

Mountain Branch Section

Incomplete section of Ohio Shale and Berea Sandstone exposed in drainage of Mountain Branch of Elkhorn Creek and along access road to Johnson Brothers Limestone Quarry, off Kentucky Highway 197, 4.7 miles south of junction with Kentucky Highway 80 in Elkhorn City, Pike County, Kentucky. Base of section is in gulley 1,000 feet FNL x 100 feet FWL of Sec. 24-J-86; top of section is along access road 1,950 feet FNL x 100 feet FEL Sec. 25-J-86 (Hellier quadrangle). Base of supplementary section is in fault contact with Pennsylvanian sandstone also exposed along access road 700 feet FNL x 925 feet FEL Sec. 25-J-86. Section measured, described, and sampled using Jacob's staff, tape, Abney level, and Brunton compass and its radioactivity profile measured using scintillometer by R. C. Kepferle, P. E. Potter, and Linda J. Provo, June 15-16, 1976.

Mississippian:	Thickness (feet)
Berea Sandstone (incomplete):	
29. Covered to top of interval with float blocks of Berea Sandstone exposed in ditch and on slope above ditch	45+
28. Siltstone (90 percent) and shale (10 percent). Siltstone is medium gray (N5) to light olive gray (5Y 6/1), weathers yellowish gray (5Y 7/2) to grayish yellow (5Y 8/4); massive; load casts	

Mississippian (continued):

	Thickness (feet)
Berea Sandstone (continued): on soles; maximum bed thickness 2.5 feet with bed thickness generally increasing upward. Interbedded shale is greenish gray (5Y 5/1), weathering to yellowish gray (5Y 6/1)	47
27. Shale (90 percent), greenish-gray (5Y 5/1), as above; with a few siltstone interbeds (10 percent) containing black, carbonaceous debris, as above; siltstone beds typically 0.3 foot thick; contact with underlying Ohio Shale is sharp and conformable	9
Total Berea Sandstone	101+

Devonian:

Ohio Shale (incomplete):

26. Shale, brownish-black (5YR 2/1), fissile, with some dark gray (N3) siltier beds which are less fissile and weather spheroidally; orbiculoid and linguloid brachiopods sparse to common in upper 12 feet; lowermost 10 to 12 feet are covered; sampled at upper contact and 28 feet above base . . .	39
25. Disturbed zone of contorted black shale beds.	7
24. Shale, olive-black (5Y 2/1), silty, micaceous, brittle, laminated but not fissile in lower 15 feet with fissility improving upward, blocky weathering; red-brown Tasmanites spores, Lingula sparse near base; black carbonaceous debris as sand- and silt-sized flecks, throughout, interbedded with thin, 0.1 foot lenticular to nodular, dark-gray (N3) to medium dark-gray (N4) siltstone beds throughout. Maximum thickness of siltstone beds is 1.0 foot at 70 feet above base (sampled). Shale sampled at base and 50 feet above base.	77
23. Siltstone and mudstone. Siltstone is light bluish-gray (5B 7/1), weathers grayish-orange (10YR 7/4), uniform, argillaceous; micaceous; abundant flecks of black carbonaceous debris; planar and cross-lamination and rare, faint current lineation on soles of beds commonly 0.1 to 0.5 foot thick; siltstone beds best developed and most abundant 5-25 feet above base of unit where it makes up	

Devonian (continued): Thickness (feet)

Ohio Shale (continued):

60 percent of unit; less abundant upward in unit; interbedded and intergradational with mudstone. Mudstone is light olive gray (5Y 5/2) to olive gray (5Y 3/2) to dark greenish gray (5GY 4/1), in beds 0.1 to 1.0 foot thick; slightly silty and micaceous; subconchoidal fracture, incipient shaly parting poorly developed; limonitic stain. More resistant beds of silty mudstone in beds 0.1 to 0.4 foot thick have uneven fracture, locally sharp-based, mottled due to bioturbation (?); rare, small flecks of shiny black carbonaceous matter; ovoid limonitic, clayey nodules 0.2 foot in diameter at 45 and 110 feet above base. Mudstone beds more abundant in upper 120 feet of unit and gradually become more fissile upward in section; mudstone sampled at 7 and at 142 feet above base; siltstone sampled at 10 and 143 feet above base. . . 147

22. Shale, olive-black (5Y 2/1) to olive-gray (5Y 3/1), micaceous; silty, with numerous very thin silt laminae one or two grains thick; silty laminae are more abundant in a zone 10 to 12 feet above base of unit, intermediate in color between pale yellow brown (10YR 5/2) and brownish-gray (5YR 4/1); burrowing in silty laminae in uppermost foot of unit with a 0.1-foot-thick, light-olive-gray (5Y 6/1) siltstone bed; abundant black coaly plant remains as much as 1 cm. in length along bedding planes; few dark brown to black spores. About 18 feet above base of unit is a low angle fault which offsets bedding. Sampled black shale at 7 feet above base. Ravine enters from east just above base of this unit. 34

21. Dark shale (80 percent) and light mudstone (20 percent), interbedded in about 25 couplets. Dark shale is brownish-black (5YR 2/2), rarely medium gray (N5), in beds ranging from less than 1 foot to as much as 9 feet thick; micaceous; quartzose silt in lighter colored laminae, which may pinch and swell; abundant resinous Tasmanites spores; and rare silt-filled burrows. Mudstone is greenish gray (5GY 5/1) to medium light gray (N6), weathering to grayish yellow green (5GY 7/2), subconchoidal to flaggy fracture; fractures coated

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
with hematite, dark yellowish-orange (10YR 6/6) to pale reddish-brown (10R 5/4); fine flecks of black organic matter. Boundaries between beds sharp. Couplets are thinnest in a zone 5 feet thick beginning 23 feet above base of unit. Unit is more resistant and hackly in appearance on slope than is underlying unit 20. Sampled greenish-gray mudstone 15 feet above base and brownish-black shale 15.5 feet above base	63
20. Mudstone (70 percent) and siltstone to very fine-grained sandstone (30 percent). Mudstone is light gray (N7), micaceous, contains very fine black shreds of organic matter; contact gradational with overlying brownish-black shale; thin, carbonaceous shale near middle of unit. Siltstone is light olive gray (5Y 6/1), laminated, in discrete beds less than 0.1 foot thick in lowest 5 feet of unit and becoming less well defined upward in the unit. Sampled siltstone 7 feet above base and mudstone at 6.5 feet above base. . . .	20
19. Covered interval.	7
18. Shale, dusky brown (5YR 2/2) to dusky yellowish brown (10YR 2/2), weathers dark yellowish brown (10YR 4/2) to grayish brown (5YR 3/2), silty, laminated, micaceous; sampled 3 feet above base . . .	5
17. Covered interval.	18
16. Mudstone (60 percent) and siltstone (40 percent). Mudstone is greenish gray (5GY 5/1), weathers light greenish gray (5GY 7/1). Siltstone and silty shale are light olive-gray (5Y 6/1), weather moderate yellowish brown (10YR 5/4), planar lamination, in beds 2-4 cm. thick. Eight feet above base is a 1-foot thick limonite-cemented zone which may be related to a fault along bedding plane; sampled limonitic zone 8 feet above base and mudstone 10 feet above base . . .	18
15. Covered interval.	12

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
14. Mudstone, greenish-gray (5GY 5/1, like unit 16; and siltstone, light olive-gray (5Y 6/1), like unit 16; sampled mudstone 2 feet above base of unit and siltstone 3 feet above base of unit.	25
13. Covered by recent (?) slide material.	125
12. Mudstone (80-90 percent), greenish-gray (5GY 5/1), and thin siltstone (10-20 percent), light olive-gray (5Y 6/1), poorly indurated, massive bedding; sampled siltstone 21 feet above base and mudstone at 21.5 feet above base	40
11. Covered interval, may be mudstone. Underlying units are measured and described from unnamed gulley.	84
10. Mudstone (80 percent), greenish-gray (5GY 6/1) and thin interbeds of dark shale (20 percent); sampled mudstone at top of unit	6
9. Mudstone, olive-gray (5Y 4/1) to greenish-gray (5GY 5/1) interbedded with equal amounts of shale, black (N1) to olive-black (5Y 2/1); fissile, brittle, fractured, micaceous, carbonaceous, Tasmanites spores; sampled dark shale 3 feet above base	7
8. Shale (80 percent), black (N1); with three interbedded greenish-gray shale beds ranging in thickness from less than 0.1 foot to 0.4 foot and separated by at least 1 foot of black shale; sampled 7 feet above base	13
7. Shale and mudstone in equal amounts; shale like unit 4 and mudstone like unit 5; beds 0.1 to 0.3 foot thick in 5 or 6 couplets; numerous minor fractures crosscut unit obliquely with offset up to 0.1 foot; sampled.	5
6. Mudstone (70 percent), like unit 5, interbedded with black shale beds like unit 4 less than 0.1 foot in thickness; mudstone beds 0.3 to 0.8 foot thick; sampled 4 feet above base.	12

Devonian (continued):	Thickness (feet)
Ohio Shale (continued):	
5. Mudstone, olive-gray (5Y 4/1) to greenish-gray (5GY 5/1), brittle; partly covered; sampled 3 feet above base	15
4. Shale, black (N1) to olive-black (5Y 2/1), fissile, brittle, fractured, carbonaceous; micaceous, Tasmanites spores; sampled 5 and 15 feet above base	22
3. Covered interval.	25
2. Shale, grayish-black (N2), highly fractured, carbonaceous; top of unit covered; sampled.	5
1. Covered interval, to stream gulley below.	20
Total Ohio Shale (incomplete)	851+
Total section measured.	952